5-2013

Analyzing the Effects of Tree Throw on the Wendt Archaeological Site

Jennifer L. Norman
St. Cloud State University

ANALYZING THE EFFECTS OF TREE THROW ON THE WENDT ARCHAEOLOGICAL SITE

by

Jennifer L. Norman

B.A., Columbia College Chicago, Chicago, 2003

A Thesis

Submitted to the Graduate Faculty

of

St. Cloud State University

In Partial Fulfillment of the Requirements

for the Degree

Master of Science

St. Cloud, Minnesota

April 5, 2013

This thesis submitted by Jennifer L. Norman in partial fulfillment of the requirements for the Degree of Master of Science at St. Cloud State University is hereby approved by the final evaluation committee.

Chairperson

Dean
School of Graduate Studies

ANALYZING THE EFFECTS OF TREE THROW ON THE WENDT ARCHAEOLOGICAL SITE

Jennifer L. Norman

SUMMARY:

The overall research goal of this thesis is to analyze how tree throw affects archaeological sites in order to gain a greater understanding of site formation processes influenced by this significant environmental factor. This research focused on whether we have the ability to determine if tree throw had previously affected undisturbed areas adjacent to the excavated tree throws areas, which have been significantly disturbed in recent years by wind and fire events. This paper will present the preliminary methods and results of the effects of tree throw on soil stratigraphy and the placement of lithic artifacts at the Wendt site in the Boundary Waters Canoe Area Wilderness located within the Superior National Forest, Lake County, Minnesota. Geoarchaeology concepts and methods were applied through the use of pedology, stratigraphy, archaeology, and dendrochronology. Recognizing potential tree throw effects, and the fact that tree throw is an important factor in site formation processes, is vital to continuing accurate research in these forested regions.

Month Year

Approved by Research Committee:

Mark P. Muñiz Chairperson

ACKNOWLEDGMENTS

I would like to thank the Minnesota Historical Society, the Superior National Forest, William Clayton, Heather Hoffman, Friends of the Boundary Waters Wilderness, Dr. Mark Muñiz, Dr. Debra Gold, Dr. Mitch Bender, the University of Wisconsin-Madison soils department, Dr. Nick Balster, Ana Wells, Dr. Philip Barak, and my brilliant St. Cloud State University colleagues. A special thanks to my parents, John and Jane, who have always supported and encouraged my diverse interests with a great deal of patience and kindness.

This project has been financed in part with funds provided by the State of Minnesota from the Arts and Cultural Heritage Fund through the Minnesota Historical Society.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter I

INTRODUCTION

Very little is known about the effects of tree throw on the displacement of cultural materials in relation to soil stratigraphy within archaeological sites. Tree throw is when weakened trees fall over as a result of a catastrophic event such as an intense fire, wind and ice storms, lightening strikes, or the attack of pathogenic organisms. By measuring the distribution of artifacts, analyzing the soil stratigraphy near a tree-throw location and in a potentially undisturbed area, and performing soil analysis tests, the influence of tree throw may be characterized. At the Wendt site, the focus site of this study, high winds and later a large fire ravaged the area. The felling of the tree pulls the root system out of the soil along with a large amount of organic, mineral, and various other materials such as cultural artifacts. David A. Norton estimates that in a forest, uprooting trees could disturb 90 percent of the soil after 10,000 years (Bonnichsen and Will 1999; Norton 1988). If Norton's estimate is correct, tree throw would have a potentially significant effect on archaeological sites within current or formerly forested areas such as northern Minnesota.

The Wendt site, located on a peninsula in Knife Lake in the Boundary Waters Canoe Area Wilderness (BWCAW) in the Superior National Forest, Lake County, Minnesota, provided a unique opportunity to study archaeological site formation processes in connection with tree throw. The trees analyzed and excavated for this tree-throw research originally fell as a result of an intense windstorm event on July 4, 1999, which affected a major portion of the BWCAW including Knife Lake (Clayton and Hoffman 2009). In 2009, the U.S. Forest Service (USFS) discovered the site after a prescribed burn and in 2010 we were able to analyze and excavate the Wendt site.

An important aspect to this research was that there is a five- to seven-year window to collect research data from the Wendt site before the tree and vegetation regrowth is too thick to collect data. Having the opportunity to travel to the Wendt site and present this research will not only give us a broader understanding of what tree throw looks like stratigraphically, but also how tree throw affects site formation processes in an archaeological context, the latter of which has been surprisingly scarce from recent research. This research will also provide additional data that may help future archaeologists identify site formation processes influenced by this significant environmental factor.

The following chapters will explain in detail the reasoning behind this research, the process of excavating, the methods used to analyze the data, and the attained results. Chapter II will review pertinent literature regarding geoarchaeological methods; give an overview of the Wendt site's history, location, ecology, and geology; discuss the subdiscipline of geoarchaeology, fire frequency and the effects of tree throw on the soil; and look at the potential impact of tree throw on the spatial relationships of cultural artifacts, including a discussion of soil turnover half-life models. Chapter III will identify the geoarchaeology concepts and methods applied through the use of pedology, stratigraphy, archaeology, and dendrochronology. Chapter III discusses the field methods; the analytic methods including soils (hydrometer test, sand fractionation analysis, particle separation analysis, forest soil analysis, and mineralogy), lithic assemblages, and the tree-ring analysis. After explaining the techniques, Chapter IV presents the results of the methods analyzed in the previous chapter by discussing the soil texture profiles, sand fractionation analysis, forest soil analysis, particle separation and mineralogy, lithic analysis and the tree characteristics. All this material will dissect the effects of tree throw in order to provide a way to analyze past human ecosystems and reconstruct this dynamic system for future research.

Chapter II

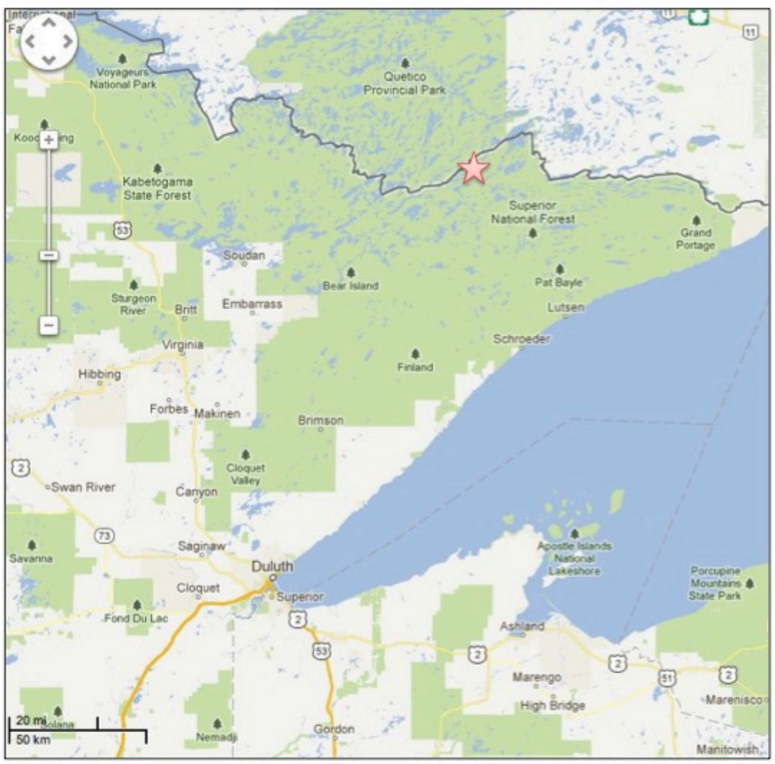
LITERATURE REVIEW AND SITE BACKGROUND

This chapter will review pertinent literature regarding geoarchaeological methods, and the effects of natural site formation processes on archaeological site formation and the interpretations derived therefrom. An overview of the Wendt site's history, location, ecology, and geology will open the chapter; then a general discussion of the subdiscipline of geoarchaeology, followed by some ideas related to the influence of fire frequency on tree throw, and the effects of tree throw on soil disturbance. Finally, the potential impact of these natural processes on the spatial relationships of cultural artifacts will be discussed, including a discussion of soil turnover half-life models.

Site Background and Setting

The Wendt site was initially burned in 2005 after a U.S. Forest Service (USFS) prescribed burn was conducted to reduce fuel loads of downed vegetation, which had the potential to ignite dangerous wildfires. In September 2009, archaeologists from the Superior National Forest (SNF), Minnesota Historical Society (MHS), Grand Portage National Monument (GPNM), and St. Cloud State University (SCSU) conducted an archaeological survey of locations, including identifying the Wendt site, on Knife Lake, which is located in the central portion of the Boundary Waters Canoe Area Wilderness (BWCAW). The prescribed burn provided ground visibility between 50 and 90 percent, which made artifact identification significantly easier on exposed surfaces and in tree throws. Some of the areas containing tree throw had cultural artifacts, soil, charcoal, and rocks clinging to the tree roots; in addition, some of this material had fallen back into a depression or pit that formerly encased the root system.

The Wendt site, located on a peninsula in Knife Lake in the BWCAW in the Superior National Forest, Lake County, Minnesota, has provided a unique opportunity to study archaeological site formation processes in connection with tree throw (see Figure 2.1 and Figure 2.2).



© Google Maps 2012

Figure 2.1

General Location of the Wendt site in the Boundary Waters Canoe Area Wilderness

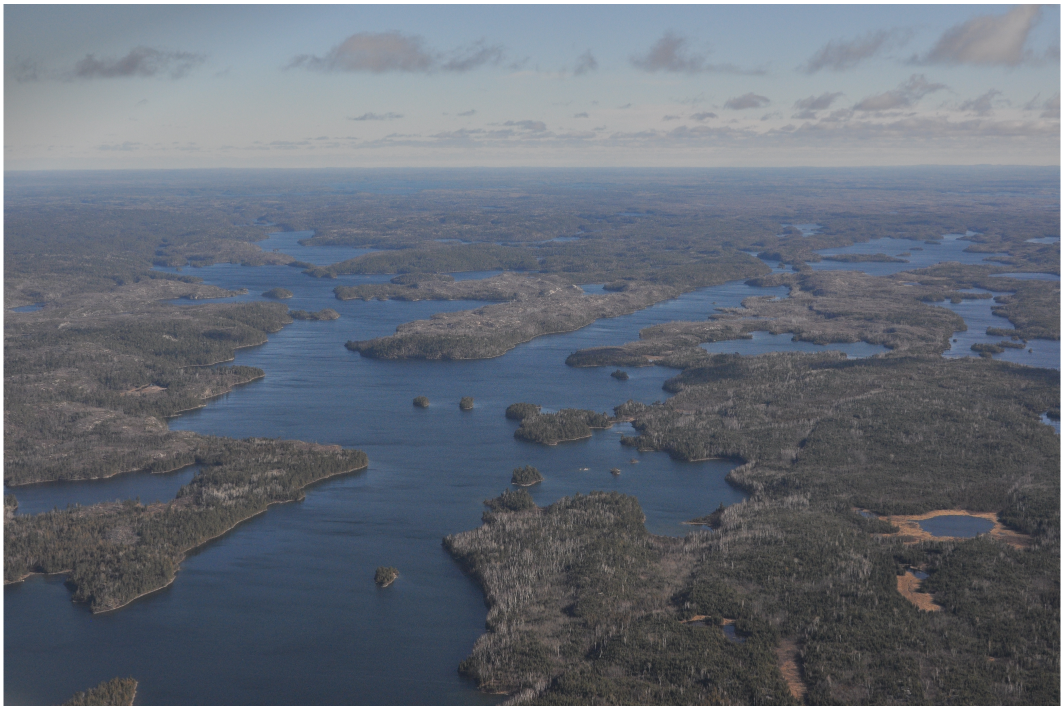


*Photo Courtesy of the Superior National Forest, U.S. Forest Service

Figure 2.2

Knife Lake Central Overview in the Boundary Waters Canoe Area Wilderness

The ecology of the BWCAW is characterized by more than 1,000 island-studded lakes with interweaving streams and portages surrounded by Boreal Forest species such as jack pine (*Pinus banksiana*) and aspen (*Populus spp.*) as well as Great Lakes-St. Lawrence forest species such as red oak (*Quercus rubra*), red pine (*Pinus resinosa*) and white pine (*Pinus strobus*) (Heinselman 1996; Clayton and Hoffman 2009). The primary species found at the Wendt site is jack pine, which is normally associated with better-drained, coarse-textured or sandy, shallow soils (Friedman et al. 2001). In general, the BWCAW soils have "developed on glacially deposited sediments such as tills and outwash structures, as well as lacustrine sediments deposited during the life span of the various glacial lakes" such as Lake Agassiz (Clayton and Hoffman 2009:10; Prettyman 1978).

The Knife Lake region's geology consists of Early Precambrian (3,900 to 2,500 million years ago) bedrock of the Knife Lake Group, which includes tool-grade Knife Lake Siltstone (KLS) (Clayton and Hoffman 2009; Bakken 1997). Knife Lake Siltstone is a greenish-gray to black meta-siltstone that occurs throughout Knife Lake as bedrock outcrops and cobbles in glacial till further south. During the Late Paleoindian stage the working of KLS was mastered to produce amazing cultural artifacts (Wendt and Romano 2009) (Figure 2.3). The Late Paleoindian stage, as with all other stages such as the Archaic, is distinct because of the people's unique stone-tool technology and style and dates from approximately 10,500 BCE (10,500 cal B.P) and 7,000 BCE (9,000 cal B.P.) (Theler and Boszhardt 2003). However, the chronology of various stages is being continually refined as new research uses improved radiocarbon dating techniques (Holliday 2000).

*Photo Courtesy of Jennifer Rovanpera

Figure 2.3

Different color variations of Knife Lake Siltstone from the BWCAW

The Wendt site, a prehistoric lithic quarry workshop, is located on top of a bedrock exposure of high-quality KLS, which was the material worked with at this site (Clayton and Hoffman 2009). In northern Minnesota, up to 90 percent of the debitage found on the Late Paleoindian, Reservoir Lakes Complex has been made from KLS (Wendt and Romano 2009). The Late Paleoindian, Reservoir Lakes Complex is a cultural grouping of archaeological sites dating to the same period (Late Paleoindian) just west of Duluth. According to Bakken (1997), KLS is abundant in the northeastern region of Minnesota, and is usually a marginal-quality material. However, in Paleoindian technological traditions, KLS may have been a desirable material for making stone tools such as adzes and similar implements because of its resiliency. Paleoindian technological traditions are based on their techniques of manipulating stone (percussion and pressure flaking) and bone or wood, the portability, and the flexibility their tools had for different tasks. After the Paleoindian period, approximately 7,500 BCE (9,500 cal B.P.)., the use of KLS was significantly lower and in certain locations the mere occurrence of KLS may be diagnostic evidence for a Paleoindian presence even if the evidence lacks a spear point (Bakken 1997).

The trees analyzed and excavated for this tree-throw research originally fell as a result of an intense windstorm event on July 4, 1999, which affected a major portion of the BWCAW including Knife Lake (Clayton and Hoffman 2009). Figure 2.4 shows the intense effect that a blowdown can have in the BWCAW.

*Photo Courtesy of the Superior National Forest, U.S. Forest Service

Figure 2.4

Before and After Example: The Results of a Blowdown in the BWCAW

According to Wood and Johnson (1978), live trees torn out of the soil by windstorms may leave even larger depressions than a naturally falling dead tree. Live trees often have an extensive root system that strongly adheres to soil and rocks above and beneath the soil surface. In naturally-falling dead trees, the root systems are significantly weakened or have already begun to decompose and do not possess the same adhering ability as the roots of live trees. Wind is the primary factor ultimately responsible for tree throw; however, tree type, tree size, soil substrate, and moisture conditions are critical passive factors in this process. Tree type and tree size are interrelated because each tree species has a limited range of characteristic dimensions for height, diameter and root system reach. Certain types or sizes of trees may be more susceptible to tree throw. One reason is those species that compete well on shallow soils do not necessarily have shallow root systems so those trees have the root anchoring to stay upright during high winds. In Menominee County, Wisconsin, the soil substrate was analyzed in 250 pit/mounds or cradle-knolls, which occur when soil and archaeological artifacts adhere to the roots of uprooted trees and then are deposited gradually on the surface or fall back into the root depression (Bonnichsen and Will 1999; Nielsen 1963; Schiffer 1987). For silty soils, the average vertical distance (bottom of cradle to top of knoll) was 0.4 m; the horizontal depression width was 1.2 m; and the average slope was 31 percent (Nielsen 1963). In sandy soils, the corresponding figures were 0.2 m, 0.8 m, and 27 percent. Additionally, trees growing on a site with a high water table may be highly susceptible to tree throw because roots of most trees will not penetrate below the water table and the moist soil may be more easily dislodged (Wood and Johnson 1978).

Geoarchaeological Methods

Geoarchaeology is a subdiscipline of archaeology that has, only in recent years, become a more viable way of interpreting and investigating sediments, soils, and landforms at archaeological sites (Waters 1992). Geoarchaeology applies the concepts and methods of the geosciences (i.e. geomorphology, sedimentology, pedology, stratigraphy, and geochronology) to archaeological sites. The three primary goals of geoarchaeology are to: 1) place a site and it's contents, through absolute dating and stratigraphy, in a relative and absolute chronological context; 2) understand the natural site formation processes (spatial context); and 3) reconstruct the former landscape that existed at the time of occupation. As opposed to approaches that lack this methodology and rely more on reasoned speculation, geoarchaeology provides a way to analyze past human ecosystems in an attempt to reconstruct this dynamic system from multiple areas of investigation.

Stratigraphic investigations, as well as site dating, are crucial and provide the framework "on which all archaeological and other scientific data are referenced" (Waters 1992: 9). Stratigraphic investigations have four fundamental objectives including: (1) subdividing and grouping the sediments and soils into units based on observable characteristics and recording the nature of the relationship between units; (2) ordering these units from oldest to youngest; (3) determining the absolute age of the units using chronometric dating techniques; and (4) correlating the units at a site with stratigraphy adjacent to that site (Waters 1992). If the Wendt site is vertically intact, meaning that one can identify discrete occupation levels that can be interpreted to reconstruct past human behavior, then this detailed analysis allows archaeologists to study cultural chronologies and site formation processes over time (Luby 2000). However, if a type of floralturbation, such as tree throw, has taken place at some point after the site was abandoned, then these techniques, which are vital to archaeology, may need to be modified to accommodate such a disturbance.

Research regarding the relationship between tree throw and archaeological sites is often focused on tree throw being misinterpreted for cultural features (Schiffer 1987). One popular example is hearths. Research in the California Channel Islands, with artifacts radiocarbon dated to approximately 30,000 to 10,000 years old, demonstrated that some areas originally thought to be the result of pre-Clovis fire pits and hearths were actually root craters (depressions) created by a combination of fire and uprooted trees during tree-throw events (Waters 1992; Wendorf 1982). The associated charcoal in the crater was probably from natural fires that burned the root masses, which then fell back into the root crater and were covered by additional soil and sediment (Wendorf 1982). Several natural processes can redden the soil such as weathering, ground water, fire, and volcanic eruptions. In the Channel Islands, the other processes were ruled out because of the association with carbon and charcoal. These soils were probably reddened by burned tree stumps and roots and in turn resembled hearths. The brick-red color of the soil was a major characteristic in identifying these areas as well as mammoth bones, possible stone tools, and charcoal associated with this soil color. In fact, the "red color" in the soil was "often outlined with carbon, and flecks of charcoal," which may have been related to one another (Wendorf 1982: 173). In or near certain "brick-red fire areas," excavators found charred mammoth bone (*Mammuthus exilis*) and, rarely, potential stone tools (Wendorf 1982: 173). The stone tools included choppers, scrapers, a core scraper, a burin and a borer. Also, it is not uncommon to find charred animal bone in the burned depression or immediate vicinity of a tree throw and fire event or a cultural hearth. It is possible that a number of the feature areas are hearths; however, research now points to burned vegetation as the cause of several hundred Pleistocene fire-pit areas in the California Channel Islands.

Bonnichsen and Will (1999) stress the importance of questioning ^{14}C-dated charcoal samples if the natural and cultural features in archaeological deposits cannot be discriminated. In order to understand how charcoal might be incorporated into an archaeological deposit and whether that charcoal is of cultural or natural origin involves using a site formation approach as emphasized by Bonnichsen and Will (1999). Recognizing the effects of geological and paleoecological processes and how they might be confused with the effects produced by humans is important. Bonnichsen and Will (1999) explore how charcoal becomes buried in archaeological sites, which includes tree throw where the depression serves as a catchment basin, and after burial may resemble fire hearths to an untrained eye. Bonnichsen and Will (1999) suggest that some ^{14}C-dated features on Paleoindian sites in the Northeast may actually date natural events and not the cultural activity that produced the archaeological remains that are potentially disturbed. Forest fires, which normally occur in a mosaic pattern, produce the majority of charcoal found in subsurface deposits. Approximately five percent of fires are catastrophic, but account for 95 percent of the acreage burned (Connor et al. 1989). These large fires can generate high winds that produce tree throw (Bonnichsen and Will 1999). According to Bonnichsen and Will (1999), the factors that distinguish a tree-throw or forest-fire depressions include: (1) only one side of the depression will have a mound; (2) the diameter of depressions will vary significantly (0.5m to 4+m); (3) the plan view of the depression varies from ovoid to irregular; (4) cross-sections of the depression are not symmetrical and profile bottoms will vary; (5) depression fill may show soil inversions and/or clasts of soil horizons; (6) fill deposits may contain charcoal from more than one burning event; (7) scattered throughout fill are rocks, artifacts and charcoal, but rarely, if ever, are these items concentrated in distinct layers; and (8) no evidence of prolonged burning (oxidation) is present in depression bottom. Alternatively, cultural features such as hearths can have characteristics that include the following: (1) a depression diameter of less than 1.0 m; (2) symmetrical depression plan view; (3) charcoal concentration on the depression floor; (4) depressions intrude through soil horizons; (5) more than one side usually contains back dirt from initial digging; (6) burned oxidation zone under charcoal layer may be found on the depression bottom; and (7) depression may be rock lined to enhance heating. To identify natural burn events that occurred around the same time as purported Paleoindian "hearths," pollen cores in Maine and Nova Scotia were analyzed and showed increased charcoal during the late Pleistocene-early Holocene period. The higher levels of charcoal may have been due to a drier climate (regional burning) and not necessarily human activity. Analyzing local pollen cores for natural charcoal peaks compared to charcoal from the archaeological record is very useful when trying to detect regional burning. One study done by Clark (1988), indicated that when analyzing charcoal in lake cores there has been shown to be a good correlation between natural burning and charcoal. Bonnichsen and Will (1999) have demonstrated the importance of using various lines of evidence to corroborate archaeological observations and interpretations when evaluating natural versus cultural formation processes. Understanding natural processes enables one to develop and distinguish between the residue of human hearths and that of tree throws or forest fires.

Researching the vertical and horizontal spatial relationships of cultural artifacts to one another, and to natural site features, has been the foundation for determining human behavioral patterns and activity at archaeological sites for over a century in our discipline (Strauss 1978; Wood and Johnson 1978). Tree throw has the ability to significantly affect those patterns and site interpretations. The terraced excavation site in Little Falls, Minnesota was this type of site (Holmes 1893). Two researchers, professor N.H. Winchell and Franc E. Babbitt, analyzed the site and determined that it dated to the Paleolithic period. W.H. Holmes later revised that date to a period of occupation "corresponding to that of our historic aborigines [tribes]" (Holmes 1893: 221). Holmes based his analysis on the material found at the site including quartz flakes and arrow points, hammerstones, "fire-marked stones – boiling or hearth stones," mounds, and natural disturbances such as tree throw (Holmes 1893: 223). Holmes noted that at the Little Falls site, Professor N.H. Winchell observed that stone artifacts were uniformly distributed through the stratum of sand that extended from the surface downward. Winchell initially interpreted this phenomenon as being the result of artifacts collected from glacial till. However, Holmes interpreted this to be the result of the decomposition of trees that had been uprooted allowing for the collection of artifacts within the pit or depression (Holmes 1893; Waters 1992). Tree throw depressions serve as a catchment basin where artifacts and organic and mineral material gradually collect (Bonnichsen and Will 1999).

Johnson (2004) conducted research after the Mustang Fire in northeastern Utah, where there were 271 known archaeological sites, dating from at least 6,000 BCE (8,000 cal B.P) with most utilized between 3,000 BCE (5,000 cal B.P.) and 1400 CE (550 cal B.P.); Johnson's research showed fire-related events such as patterned soil stains, charred bone concentrations, uprooted trees, ash-charcoal stained strata, buried and exposed artifacts, and charred wood and bone materials on open surfaces. Johnson (2004) states that tree-throw depressions often had a surrounding rock ring that appeared quite substantial in the direction of the trunk fall. Additionally, in the circular depressions where the roots had burned significantly, ash filled much of the space 15 centimeters or more deep; however, general depressions throughout the site filled with a combination of ash and stained fine sediments. These are all important aspects to look for when working in the BWCAW, because we are also looking at an archaeological site that was fiercely burned. The idea that the sediment in the depression is different than the surrounding soil might provide a means of identification in tree-throw occurrences.

The Holcombe site, located in Macomb County, Michigan, was excavated in the 1960s by the University of Michigan Museum of Anthropology (Fitting et al. 1966). The site has been radiocarbon dated to approximately 11,000 ^{14}C yrs B.P. (9,000 BCE). Prior to being burned off for agricultural purposes, the area was heavily wooded. Fitting et al. (1966) identified eight features (Feature Number 1 – 8) as cultural, natural or inconclusive by the following criteria: location, measured area east to west and north to south, deepest point below plow zone, soil color differences, identification of charcoal and/or ash, cultural material, root patterns, and decayed organic material. Feature Numbers 1, 2, 4, and 8 were documented as associated with the main occupation of the site. These features all lacked charcoal concentrations, and Feature Number 2 contained cultural material and calcined bone fragments. Feature Numbers 1, 4, and 8, which were very similar to Feature Number 2, did not contain much cultural material or bone fragments. Feature Numbers 3 and 7 appeared to be, what Fitting and colleagues termed, "burned-out stumps." "These are areas of dense charcoal concentrations, beds of grey ash, and discolored, hardened reddish-brown sand which can be followed to a considerable depth" (Fitting et al. 1966: 16). Six additional burned-out stumps were identified within the excavated area, but were not numbered as features. The identification of Feature Numbers 5 and 6 were inconclusive; however, they were possibly later-occupation hearths or natural disturbances. Artifacts were found spread over the area and not concentrated near or in depressions like at the Wendt site. Plowing may have caused this artifact disturbance so this does not mean tree throw was unimportant. Some of the diagnostic characteristics of these features are similar to the Wendt tree-throw characteristics including a depression area, soil differences (i.e. sandy soil), charcoal detected in depression, cultural material identified, and the Wendt tree stumps were also burned. The Wendt site is different from the Holcomb site in that no bones were found, the soil was shallow with many rocks and pebbles, no plowing has affected the area, and distinct buried charcoal layers were identified. It is possible that some or most of the features at the Holcomb site were tree-throw locations, but that is inconclusive because of vague descriptions and the disturbance of the plow zone.

Effects of Tree Throw, Soil, and Fire

The combination of soil depth, tree age and the fire rotation period may control the probability of tree throw. Recent increases in tree throw may be related to current rotation periods, which may be considerably longer than typical intervals between fires during presettlement periods and now may be longer than the maximum life span of most tree species.

Tree throw, which is the most obvious form of floralturbation by mixing of soil by plants, is an important pedologic process in forested and formerly forested areas (Schaetzl et al. 1989). Tree throw can significantly rework sediments in forested regions over hundreds or thousands of years and may be the principal mechanism of soil movement in forested areas (Malde 1964). A tree is uprooted when subjected to lateral forces on the crown and stem that exceed root-soil holding strength and that fail to break the stem (Bonnichsen and Will 1999). Soil and archaeological artifacts adhere to the network of roots of uprooted trees and are pried upward; those materials are then deposited gradually on the surface or fall back into the root pit and contribute to characteristic pit/mound, or cradle-knoll, microtopography and inverted soil horizons (Bonnichsen and Will 1999; Schiffer 1987). When trees are uprooted, they leave a depression or pit that charcoal, bone, and pollen can be transported into by wind, sheet erosion, or other mechanisms (Bonnichsen and Will 1999; Johnson 2004). The pits mark the former position of the roots and a mound forms where soil slumps off a deteriorating, decomposing, displaced root system. Tree throw is also characterized by sharp changes in the soil profile (Ulanova 2000). According to research conducted in boreal spruce forests of the central Russian Plain, the upper horizons are lost in the area of the pit and in other areas the profile is buried by a combination of organic and mineral material or pure organic material (Ulanova 2000). Right after the tree throw event, the taxonomy of these soils differs significantly from the original ones. Eventually, the roots and trunk decompose and disappear in 50-200 years while the pits and mounds are preserved. After major tree-throw uprootings, it is practically impossible to reconstruct the background soil combinations and processes within the 200-300 year cycle. Even though it is also challenging for the soil to return to the approximate original conditions following minor tree-throws and the creation of shallow pits, most become similar to those of undisturbed soils after 100-200 years (Ulanova 2000).

The amount of soil disturbed by tree throw is dependent on the depth and spread of the root system (Bonnichsen and Will 1999). The soil in this area of the BWCAW is approximately 30-70 cm deep, which complements the jack pine tree type in the area. At the Wendt site, Tree Throw 1 had a depth of approximately 35 cm, Tree Throw 2 was approximately 23 cm deep, and Tree Throw 3 was approximately 35 cm deep. It is possible that because the soil is so shallow in this region, a significant portion of the soil profile will be A and B horizons, which are levels within the soil that have distinctive physical and chemical properties (Waters 1992). The A and B horizons are commonly the top two horizon layers in the soil. It is estimated that in the northern hardwood regions of North America, most of the A and B soil horizons will be floralturbated over 500 years (Wood and Johnson 1978; Mueller and Cline 1959; Olson and Hole 1967; Denny and Goodlett 1956).

In addition to soil depth, the diameter at breast height (dbh) measurement, which is the standard method of expressing the diameter of the trunk of a standing tree, assists in assessing the fertility and regeneration of these jack pine trees. The assessment is also based on the age of the tree, fertility of the soil and the depth of the root system. The jack pine averages 20-25 centimeters in d.b.h. and 17-20 meters in height (Rudolph and Laidly 1990). Research after the Mustang Fire demonstrated that the circular depressions from tree throw filled with ash-stained sediments up to 15 cm or more deep (Johnson 2004). However, the Mustang Fire site had Ponderosa pine trees, which are much larger than jack pine and would have created larger depressions. According to the U.S. Forest Service, ponderosa trees averages 263 centimeters in d.b.h. and 70.7 meters in height. Brewer and Merritt (1978) reported an average of 11.9 m^2 of soil surface disturbed at the base of a single uprooted tree in a climax Beach-Maple forest in Warren Woods, Michigan. However, only trees with a 25.4-centimeter or larger d.b.h. were measured for this research, which looked at the effects of tree throw on canopy diversity (Brewer and Merritt 1978). It was discovered that trees larger than 76 centimeters d.b.h were more susceptible to tree throw than smaller trees and that more soil was moved or disturbed with these larger trees.

The combination of soil depth, tree age and the fire rotation period may control the probability of tree throw, and recent increases in tree throw may be related to current rotation periods that are considerably longer than the maximum life span of presettlement tree species. An important feature of the BWCAW is the reduced fire frequency in recent history. Since 1600 C.E. (or Common Era, a designation for the calendar era beginning year 1), over 90 percent of the BWCAW forests have burned at least once with average fire frequency intervals of approximately 60 to 70 years; particular areas may range from less than 10 years to over 200 years (Heinselman 1969, 1973; Swain 1973). Some jack pine forests probably had fire frequency intervals of 50 years or less (Heinselman 1973). Jack pine species reach reproductive maturity at 20-30 years with seed rain from cones happening quickly after a fire; therefore, fire return periods of 50 years or less would mean fairly regular regeneration prior to fire suppression (Benzie 1977; Friedman et al 2001). Frelich and Reich (1995) state that since 1910, fire rotation periods have changed from approximately 50 to 100 years during presettlement times to current predictions of more than 1000 years because of fire suppression, climate, and land-use change. Since most of the forests in the BWCAW are less than 300 years old, many fire history studies are limited to the period after European contact (Swain 1973). However, according to Heinselman (1973), fire was a major factor in northern Minnesota's forests prior to European contact as indicated by charcoal fragments and fossil evidence found in lake sediments, peat bogs, and glacial deposits. The reduction in fire frequency allows the trees to grow larger and more vulnerable to tree throw in shallow soils (Brewer and Merritt 1978; Frelich and Reich 1995). Jack pines prefer to grow in better-drained (larger soil particles), sandy or loamy soils that have a shallow depth, which occurs at the Wendt site (Friedman et al. 2001). As the trees grow taller and the root system has limited depth in shallow soil, the root system is less able to keep the tree upright in strong winds. The tree will continue to grow taller, yet the root system will lie just below the surface level. The shallow soil dictates the depth of the root system, which is susceptible to being torn out of the ground in a blow down such as the one in 1999 in the BWCAW. As a result of fire suppression the trees may be growing larger today and more susceptible to tree throw than in the more distant past; therefore tree throw that *significantly* impacts buried archaeological deposits might be a more recent phenomenon on this archaeological site. However, this does not mean that tree throws were absent in the past. Tree throws occurring thousands of years ago might have affected a much smaller area vertically and horizontally because of their smaller root system and base size.

Soils, "the weathering profiles developed by the in-place physical and chemical alteration of preexisting sediment," play an important role in archaeology through the analysis and interpretation of depositional layers, or strata (Luby 2000; Waters 1992: 40). Soil is a dynamic, open system, in which a variety of processes (e.g. floralturbation) move not only soil, but also objects (including artifacts) from their original undisturbed or *in situ* position (Wood and Johnson 1978). In order to understand the spatial and temporal relationships among multiple sedimentary layers, or artifacts within those layers, archaeologists carefully consider the characteristics of individual soil layers and strata (Luby 2000; Waters 1992).

Norton (1988) established a soil turnover half-life model (the period of time in which half the soil has been turned over) to determine the area of disturbed soil in a New Zealand forest. His estimates are based on several factors: The common tendency of trees to become reestablished on soil mounds formed from previous tree throws, the time it takes for a forest to reestablish itself in an opening and mature, and the propensity of a forest to be blown over again. If early people in northern Minnesota were populating forested regions around 10,500 ^{14}C yr B.P., then the potential for uprooted trees to cause soil disturbances to the archaeological sites they abandoned is as high as 90 percent (Bonnichsen and Will 1999; Norton 1988). Holmes (1893) states that as a result of these significant soil disturbances such as tree throw, we may misinterpret the spatial and temporal relationships among archaeological artifacts by thousands of years. However, the types of trees and growing conditions in New Zealand could be somewhat different than in Northern Minnesota, which is a harsher climate. Depending on the tree densities, site fertility, tree species and growth rates, applying the Norton model to the Wendt site might produce a different amount of disturbance.

A surprisingly small number of studies have been done on the effects of tree throw on archeological interpretation, considering its potential importance when interpreting the archaeological record. Depending on the area, the influence of tree throw on archeological site interpretation may vary from negligible to dominant. However, an archaeologist should be aware and strive to use every piece of evidence and breadth of knowledge about the relationship between the cultural material and ecological material to determine the magnitude of this influence.

Chapter III

METHODS

In this chapter, I identify the geoarchaeological concepts and methods applied through the use of pedology, stratigraphy, archaeology, and dendrochronology from samples taken at the Wendt site in 2010. The chapter begins with a discussion of field methods, which include the sampling strategy and excavation procedures. Following the field methods are the analytic methods consisting of three main sections including: soils, which comprise soil texture with the hydrometer, sand fractionation analysis, particle separation analysis, forest soil analysis, and mineralogy; lithic assemblages, which considers cultural designations, labeling, and metric measurements of collected material; and the tree-ring analysis of tree-stem cookie samples and stem cores. With these methods in mind, I am trying to understand the natural site formation processes in the presence of tree throw in order to provide a way to analyze past human ecosystems and reconstruct this dynamic system for future research.

In September 2010, a team of archaeological graduate students under the direction of Dr. Mark Muñiz from St. Cloud State University (SCSU) along with U.S. Forest Service (USFS) archaeologists, William Clayton and Heather Hoffman, assisted in excavations at the Wendt site looking at the effects of tree throw on a number of different elements including soil horizons, tree features and lithic assemblages. The research at the

Wendt site was based on a horizontal and vertical cluster sampling strategy, which incorporated separate stratified soil-horizon layers.

Field Methods

The first step was to conduct a survey of the general site area and tree-throw root systems to make certain three sample trees were chosen that represented the site's universal elements. Three tree-throw root systems were chosen by a set of essential criteria that began with a combination of different size stem diameters and root systems, which were classified into large, medium and small. Three different sizes were chosen because it would have been incredibly difficult to find trees the exact same size and it would hopefully show variability or similarities in the tree-throw areas that were excavated. The three trees were chosen with the following criteria: one consistent tree species, jack pine; cultural artifacts must be present within the root system and colluvium; for safety reasons, the tree must have completely fallen to the ground; the tree must be ring porous for past fire analysis and dating purposes; and finally, no visible obstructions may be present within two meters vertically or horizontally to the root system above ground. Measurements of the tree stem by diameter at breast height (d.b.h.) were taken of the three selected trees to designate large, medium and small. Diameter at breast height is used to measure tree size and to estimate tree biomass (plant materials used as fuel). Because the tree stems were on the ground laying horizontal, significantly burned and had been in the process of decaying as a result of the 2005 prescribed burn, the process of acquiring the dbh was challenging. We also needed to make sure the tree-stem cookie (section cut away from stem) was as intact as possible so the tree-ring dating could be measured as accurately as possible. We measured approximately five feet (152 cm) above the top of the tree roots and cut a one-inch thick section out of the stem. The diameter of the tree-stem cookie was then measured to determine dbh. Tree-Throw Unit 1 and 2 may have fallen together since they are located adjacent to one another; however, they were excavated as separate units.

After the sample trees were chosen, the excavation unit boundaries were measured and outlined. In contrast to most traditional excavation units, the unit line needed to extend from the center of the tree stem over the top of the root system out two meters to the ground (see Figure 3.1). The reason for this layout was because of time constraints at the site and also, after excavating half of the disturbed and intact areas, to see a clear wall profile of the approximate center of the excavated area. The complex unit set up consisted of the unit lines extending 50 cm laterally and two meters horizontally from the center of the tree stem.

Figure 3.1

Tree-Throw Unit 1 and Tree-Throw Unit 2 Prior to Excavation

After the unit lines were secured, each unit was photographed and recorded with a photo board. The excavation process then began by using trowels and brushes to excavate the root system, which was the starting point in each of the three tree-throw units (see Figure 3.2). The identification of different levels was based on changes in stratigraphy (texture or color) and not by controlled depths (e.g., five- or 10-cm levels). Since no soil strata were identified within the root system, one three-cup soil sample was collected from the general root-system area for all three units. All other excavated soil was dry-screened using quarter-inch mesh to isolate the cultural artifacts. All cultural artifacts were gathered from the screen and placed in level bags for further analysis in the SCSU laboratory.

Figure 3.2

Excavation of Root System and Colluvium in Tree-Throw Unit 2

After the root system was excavated, the area below the roots, the colluvium, was excavated, using a trowel or brush, and separated into levels either by visual changes in the soil color or soil texture (soil strata), which was most obvious in Tree-Throw Unit 3. The thickness of the soil strata-sampling units varied from as thin as three centimeters to as thick as 45 centimeters. I decided not to use the standard five- or 10-centimeter thick excavation levels because I wanted to follow the natural stratigraphy. The time restriction at the site was also incorporated in the decision to choose the natural stratigraphy over the standard. The excavation in the colluvium stopped at either the bedrock or when we visually encountered another soil stratum that indicated sub-colluvial deposits. In Tree-Throw Unit 1 and 2, one three-cup soil sample was taken from the general colluvium area in each respective unit. In Tree-Throw Unit 3, three three-cup soil samples were taken from colluvium areas that were potentially different from each other. These strata included the Colluvium (Stratum 1), Colluvium (Stratum 2), and Colluvium (Stratum 3). Colluvium (Stratum 1) was on top of a thin layer of charcoal and Colluvium (Stratum 2) was beneath that layer. Colluvium (Stratum 3) was slightly different in color (more reddish brown) and texture (more wet and possibly more silt) and contained a high amount of cultural material. All remaining soil excavated from the colluvium was screened through quarter-inch mesh, and artifacts were pulled and placed in layer bags by strata for further analysis at SCSU. All three excavation units contained a layer of charcoal within the colluvium, which was thought to be as a result of the 2005 USFS prescribed burn in the area. Charcoal samples were extracted from the three units; however, funding did not enable testing of this material.

In Tree-Throw Unit 3, the depression area was more defined than in Tree-Throws 1 and 2, which resulted in a separate excavation section of the depression within Tree-Throw Unit 3. A slight color and texture variation, different from the colluvium areas yet similar to Stratum 2 and Stratum 3, was detected in the depression area of Tree-Throw Unit 3 and as a result cultural material was collected in two separate strata. The two strata included the Depression (Stratum 2) and Depression (Stratum 3); however, bulk soil samples were inadvertently overlooked from these strata; a consequence of having several people working on different units simultaneously under demanding conditions. The excavated soil in Tree-Throw Unit 3 was screened through quarter-inch mesh, and cultural artifacts were pulled out and bagged by stratum for later analysis at SCSU.

The final excavation step was to focus on the potential undisturbed area adjacent to the tree throw depression, which was excavated by soil strata based on a visual analysis of color, a textural analysis by hand, soil structure, and horizon features. The undisturbed area was excavated using a shovel, trowel and brush. The thickness of the soil strata-sampling units in this area varied from as thin as three centimeters to as thick as 31 centimeters. Excavating stopped when bedrock was encountered. The natural division of strata resulted in Tree-Throw Unit 1 containing Strata 1 through 3, Tree-Throw Unit 2 containing Strata 1 through 4, and Tree-Throw Unit 3 containing Strata 1 through 3. The strata are similar; however, it was unknown in the field if they were exactly alike. The similarities were estimated by color, hand-texture, structure and feature tests. For each of the three units, three-cup soil samples were taken by stratum with the remaining soil screened through quarter-inch mesh to isolate artifacts, which were collected and bagged by stratum. Field specimen numbers (FSN) were assigned to each soil sample and each set of lithic artifacts designated by soil strata. The FSN assisted in the electronic cataloging of material once the collection arrived in the SCSU laboratory. Additional photographs were taken of each unit throughout the excavation process, as well as of significant cultural artifacts and the surrounding area for a record of the vegetation. Three soil profiles were drawn of the northwest and southwest walls within all three units to identify strata locations (see Figures 3.3, 3.4, and 3.5). These profiles run the two-meter length of the excavation unit.

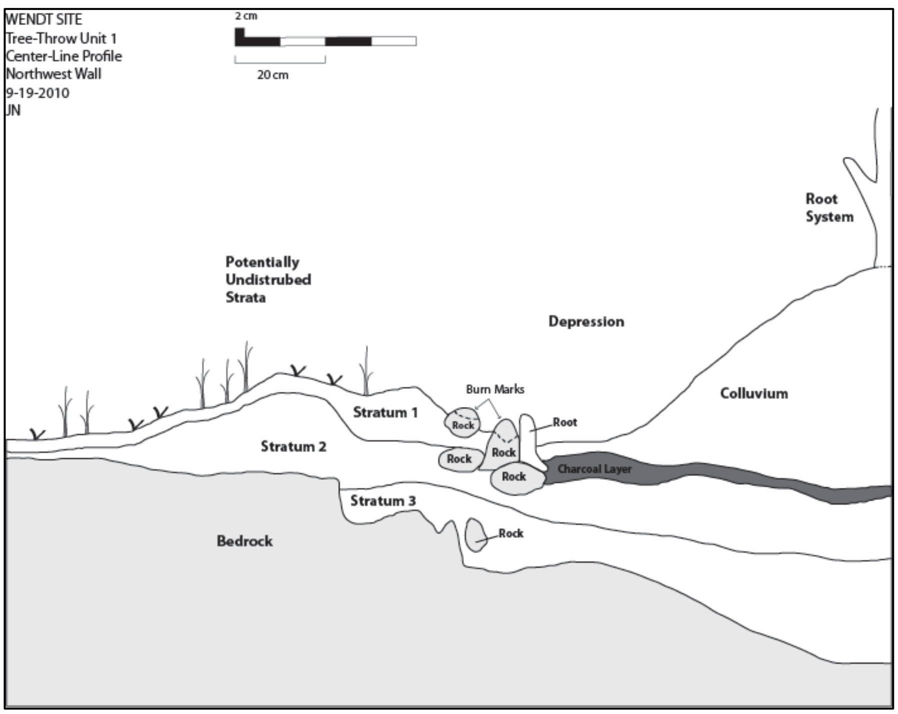


Figure 3.3

Northwest Wall Soil Profile of Tree-Throw Unit 1

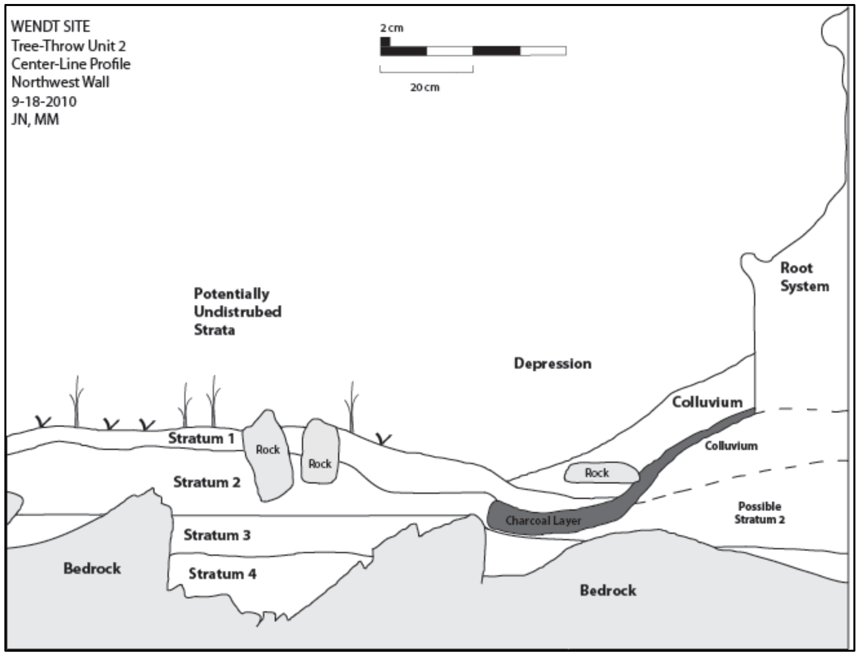


Figure 3.4

Northwest Wall Soil Profile of Tree Throw-Unit 2

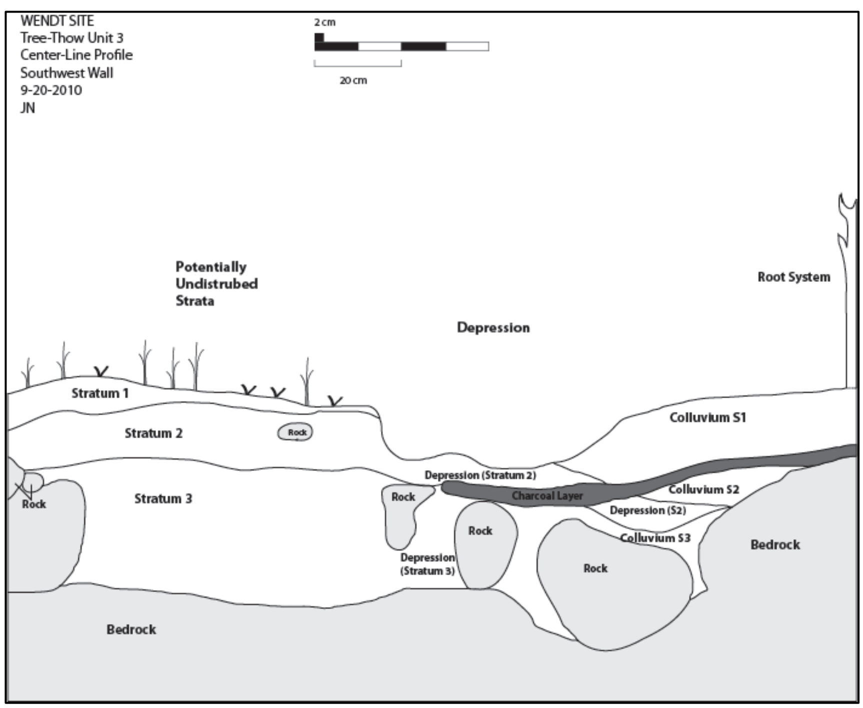


Figure 3.5

Southwest Wall Soil Profile of Tree Throw-Unit 3

Twelve stem-core samples, 11 jack pine trees and one aspen tree, were taken from standing trees within the vicinity of the tree-throw excavation area (see Figure 3.6). Additionally, one-inch thick tree-stem "cookies" were cut from each of the three fallen trees for dating and identification of possible burn scars (see Figure 3.7). Finally, Global Positioning System (GPS) measurements were taken of the location of the three tree-throw units as well as the 12 stem-core locations for internal research at SCSU.

Figure 3.6

Stem Core Extraction at the Wendt Site

Figure 3.7

Tree-Stem "Cookie" Preparation from Tree-Throw Unit 1

Analytic Methods: Soils

Analysis of the soil in relation to lithic artifacts is an important aspect of interpreting the archaeological record. "Soil is not a static body; it is a dynamic, open system, in which a variety of processes may act to move not only soil matter, but objects (including artifacts), from one position to another" (Wood and Johnson 1978:317). As seen in this research, tree throw appears to be one of those processes that significantly affect the soil and movement of artifacts.

From all excavation units, approximately three cups of soil were collected from specific strata and divided into separate bags in order to use in various soil testing procedures. The majority of the soil was used at the University of Wisconsin, Madison (UW Madison) for processing in the Department of Soil Science. At UW Madison, 18 samples were analyzed for soil texture with the hydrometer method, and eight samples were used in the particle- size separation test. A Forest Soils analysis was conducted on 18 samples at the University of Wisconsin Soil and Plant Analysis Lab (UW Soil and Plant Analysis Lab), which is a branch of the UW Department of Soil Science in Madison, Wisconsin. Neutron Activation Analysis (NAA) and X-ray Diffraction (XRD) were used to measure the elemental composition of certain soil samples. Two samples were sent to H&M Analytical Services for the XRD analysis and 10 samples were sent to the University of Wisconsin Nuclear Reactor Laboratory (UWNR) for NAA.

The hydrometer test. The initial laboratory analysis to determine the particle size/texture characteristics for the soil strata at the Wendt site used the hydrometer method, which was first introduced to the scientific community by Bouyoucos (1927). For this method, a gauged amount of soil is suspended in water and using a specialized hydrometer, the suspension density is determined (Bohn and Gebhardt 1989). The physical proportions of three sizes of primary soil particles (sand, silt and clay) are quantitatively determined by their settling rates (Briggs et al. 2006). As soil particles settle, the suspension density decreases as a result of larger particles, such as sand, settling faster (Bohn and Gebhardt 1989). The particle size and summation percent remaining for the larger size particle can be calculated at each time point (30, 40, 90 seconds and four hours) using the observed level of the hydrometer. “The accuracy of the size class distribution estimate depends on a constant temperature, careful particle dispersal, and proper timing of the density observations” (Bohn and Gebhardt 1989:81).

There are two general procedures in the particle-size/texture analysis (Dr. Nicholas Balster and Ana Wells, personal communication 2010). The first is the removal of soil organic matter as described below.

1. Create a designated numbering sequence for the analysis (e.g. H1, H2, etc.) and compile all the samples in a spreadsheet format in addition to a hardbound notebook. This number will be very important when soil is being transferred from one container to another throughout the process.
2. If the soil is moist, place in an open, labeled container (e.g. paper bag) in an oven overnight for drying at 70° to 80° Celsius (C).
3. Once the soil is dry, sift through a 2-mm screen. Collect any archaeological artifacts, separately bag anything larger than 2 mm, and replace the sifted dry soil in a sealable bag containing the corresponding analysis number.
4. Weigh (preferably in grams) and label each flask individually. Record weight in notebook to the nearest 0.1 grams (g).
5. Add approximately 50 g of dry soil to the flask (see Figure 3.8).

Figure 3.8

Dry Soil Samples

6. Calculate the difference between the flask weight and the flask + soil weight to get the exact soil weight (see Table 3.1).

Table 3.1

Soil Sample Weight Calculated by Location

Flask ID	Unit No.	Location	Flask Wt (g)	Flask + Soil Wt (g)	Soil Wt (g)
H1	1	Roots	207.84	259.28	51.44
H2	1	Colluvium	197.18	247.64	50.46
H3	1	Stratum 1	221.74	272.09	50.35
H4	1	Stratum 2	213.24	262.78	49.54
H5	1	Stratum 3	211.84	262.26	50.42
H6	2	Roots	159.39	208.80	49.41
H7	2	Colluvium	215.41	265.05	49.64
H8	2	Stratum 1	172.53	221.83	49.30
H9	2	Stratum 2	207.85	257.19	49.34
H10	3	Colluvium (Stratum 1)	209.20	259.82	50.62
H11	3	Stratum 3	142.60	191.90	49.30
H12	3	Stratum 1	221.07	272.64	51.57
H13	2	Stratum 3	216.41	266.71	50.30
H14	3	Stratum 2	162.58	213.41	50.83
H15	2	Stratum 4	207.27	257.46	50.19
H16	3	Colluvium (Stratum 3)	211.06	260.49	49.43
H17	3	Colluvium (Stratum 2)	211.13	262.07	50.94
H18	3	Roots	204.94	255.85	50.91

7. Add 25 milliliters (mL) of distilled water to each flask, swirl to completely mix and wet all soil in flask.

8. In a hood, add 10 mL of 25 percent Hydrogen Peroxide (H_2O_2) to the sample and swirl the mixture, which may begin to effervesce. When the reaction subsides, add more H_2O_2 until no more foaming occurs.

9. Put the flask sample on a hot plate at 200°C and heat the sample for one hour or until the sample changes color from dark brown (or black) to grey (or tan) (see Figure 3.9). CAUTION: the samples may froth over with the addition of heat. If this occurs, add a very small amount of water to dissipate the reaction. Never leave the sample unattended when on the hot plate.

Figure 3.9

Soil Samples Heating on Hot Plate

10. After the samples have changed color completely, turn off the hot plate and put the samples into a drying oven at 105°C and allow drying overnight.

The second step is the particle size analysis by the hydrometer method as described below.

11. Remove the sample from the drying oven and let cool completely.
12. Add 100 mL of a 5 percent sodium hexametaphosphate (amorphous sodium polyphosphate) (NaHP) solution into each dried soil sample. Shake until the

material is well mixed and cover with a protective seal (e.g. Parafilm) (see Figure 3.10). Allow the mixture to stand overnight.

Figure 3.10

Soil Flasks Covered Overnight in Preparation for the Mixer

13. Remove the film cover and transfer the entire contents of the flask to the cup of a soil mixer, using a wash bottle with distilled water, removing all of soil mixture from flask (see Figure 3.10).
14. Attach the mixer cup to the soil mixer and stir for two minutes.
15. Transfer the entire contents of the mixer cup to a 1-liter graduated cylinder, using a wash bottle with distilled water to remove all soil from the cup, and bring the content to the 1000 mL mark (see Figure 3.11).

Figure 3.11

Soil Cylinders (1000 mL) Filled with Soil and Distilled Water

16. Fill a 1-liter graduated cylinder with 100 mL of NaHP and 900 mL of distilled water. This is the blank and should be considered and measured as one of the samples.
17. To regulate the temperature, place the graduated cylinders in a water bath set at a constant temperature of 30°C and allow cylinders to sit overnight (see Figure 3.12).

Figure 3.12

Placing the 1000 mL Soil Cylinders in the Water Bath

18. Mix the soil with a plunger until a uniform suspension is obtained. Gently remove the plunger, note the time immediately and record it in your notebook.
19. Place a hydrometer gently into the suspension after removing the plunger and take a reading at the 30, 40 and 90 seconds.
20. Again, place a hydrometer gently into the suspension and take a reading at the end of 4 hours.
21. Determine a hydrometer correction factor for the density of the NaHP by inserting the hydrometer into the blank after 30, 40 and 90 seconds and after the 4-hour mark.

The calculations for determining the particle size percentage is as follows:

Corrected 30-second reading = 30-second reading – blank reading at 30 seconds

Corrected 40-second reading = 40-second reading – blank reading at 40 seconds

Corrected 90-second reading = 90-second reading – blank reading at 90 seconds

Corrected 4-hour reading = 4-hour reading – blank reading at 4 hours

$$\text{Percentage (silt+clay)} = \frac{\text{Corrected 30-second reading}}{\text{Weight of dry soil sample}} * 100$$

$$\text{Percentage clay} = \frac{\text{Corrected 4-hour reading}}{\text{Weight of dry soil sample}} * 100$$

Percentage silt = Percent (silt+clay) – percent clay

Percentage sand = 100 – (silt + clay)

After the particle-size calculations are completed and you have a percentage for each of the sand, silt and clay categories, the Soil Texture Triangle is used to estimate the appropriate designation of that soil (see Figure 3.13).

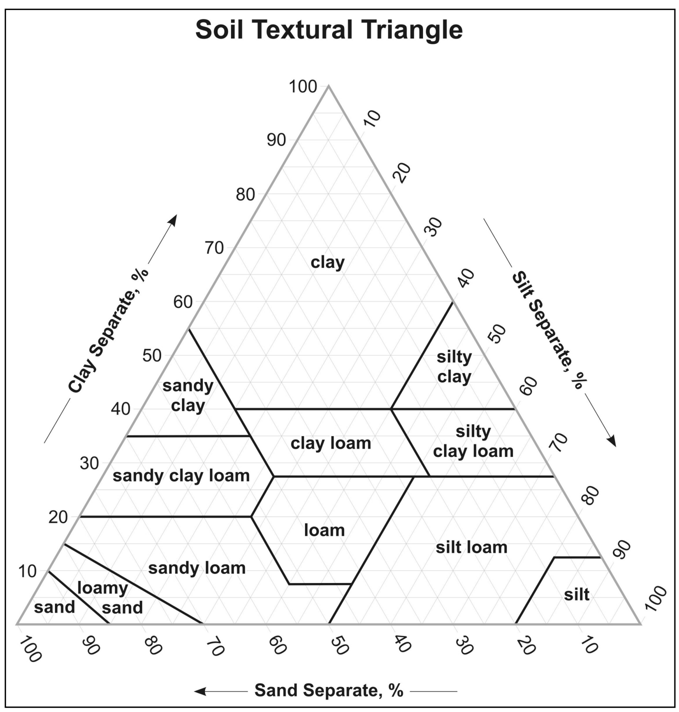


Figure 3.13

Soil Textural Triangle of the U.S. Department of Agriculture

Sand fractionation. After concluding the hydrometer testing and calculating the measured results, the silt and clay portions of each of the 18 soil samples were separated from the sand portion by water screening through a 53-micron sieve. The sand collected in the sieve was then poured into glass beakers using a wash bottle with distilled water, removing all of the sand from the sieve. The glass beakers, labeled with the corresponding sample number, were then placed in an oven overnight at approximately 75° C to dry the sand.

When completely dry, the sand was removed from the glass beakers and transferred to a group of sieves of diminishing size. The sieve sizes used for this experiment were 1 mm, 500 microns, 250 microns, 150 microns, and 53 microns. Any material sized below 53 microns was considered silt or clay and was measured, but not collected. Prior to the transfer of sand, each sieve was weighed separately in order to later calculate the sand weight without the sieve. The sieves were linked together and placed securely on a sieve shaker for four minutes, which created consistent, continuous movement to allow the sand particles to fall through the sieves (see Figure 3.14). The sieves were then removed from the shaker and each sieve was weighed with the collected sand.

Figure 3.14

Sieve Shaker Fractionating the Sand Particles

The sand was then transferred to plastic bags labeled with the corresponding sample number, sieve size and total weight (see Figure 3.15). The experimental steps and resulting data (e.g. sand weight) were also recorded in the field notebook.

Figure 3.15

Sand Fractionation Size Divisions

The particle separation test. The particle size separation test was conducted in preparation for mineralogy testing, phytolith analysis, and a textural analysis of the percentages of sand, silt and clay extracted from soil. For one sample, this process takes approximately eight days depending on the amount of clay in the sample. We began this process using three-gallon jugs; however, it was later decided that 800 mL jars would be sufficient for the measured amount of soil in this experiment. The procedure for separating soil particles follows below (Dr. Phillip Barak, personal communication 2010). In the interest of simplicity and efficiency, removal of organic matter by hydrogen peroxide (H_2O_2) and removal of free oxides by sodium dithionite ($Na_2S_2O_4$) was judged unnecessary for chemically dispersing the soil particles for this experiment.

1. Preparations:
    a. If processing multiple samples, confirm that two 800-mL, preferably clear, glass jars are available per sample. It is suggested that one use either two different shaped jars or two different color lids for easy visual confirmation of particles within sample jars.
    b. In order to make sure the jars and lids are clean, rinse with deionized water prior to adding any soil.
    c. Create a numbering sequence for this analysis; label all jars with this number (e.g. "[S] 22 Soil" and "[S] 22 Clay") and compile a comprehensive listing of the samples in a spreadsheet format.
    d. Create a table list of sample numbers in a hardbound notebook for reference during the experiment.

The initial steps are directed at extracting the clay element.

2. Measure 70 g of soil (preferably dry), remove any pebbles and add soil to one jar. For this experiment, the soil jars had blue lids.
3. Measure and add approximately 24 g sodium chloride (NaCl) to the soil jar.
4. Fill the jar with deionized water, cover with a leak-proof seal (e.g. Parafilm), close lid so the parafilm is between the glass jar and the lid and shake contents well to mix.
5. Place securely on a shaker (make certain no jars are leaking) and shake the contents on low to medium intensity overnight.
6. Remove the soil jars from the shaker; shake loose any particles that may have settled on one side of the jar and set jar upright.
7. Allow silt to settle according to Stokes' law[1], which is approximately 10 cm for every eight hours, leaving only clay-size particles above (see Figure 3.16).

Figure 3.16

Soil Jar Dispersion After Eight Hours

lvlvlv

[1] Stokes' law, developed by George G. Stokes in 1851, uses fluid dynamics to relate the frictional and gravitational forces exerted on spherical objects to the object size, density and fluid viscosity (Batchelor 1967).

8. After eight hours, decant (decanting is done with a siphon at a slow rate so as to not disturb the soil particles that have settled to below the 10-cm depth) the top 10 cm of liquid from the soil jar into a second glass jar, which will hold the collected clay (clay jars). For this experiment, the clay jars had white lids. It is possible that the first or second decanting may not collect a sizable amount of clay because of the high salt concentration. If the particles settle very quickly in the soil jar (blue covered jars) so that after an hour or two 10 cm of clear water exists above the soil that has settled, the solution can be decanted, discarded and replaced with deionized water without waiting the normal eight hours.
9. Replace the lost volume in the soil jar with deionized water, and shake contents thoroughly. It is not necessary to shake the soil jar overnight.
10. Add approximately 15 to 20 g of calcium chloride ($CaCl_2$) to the decanted clay suspension in the clay jars (jars with white lids) to flocculate[2] the clay for collection. Mix contents thoroughly and let settle.
11. Once the clay has flocculated, the clear supernatant can be decanted and discarded.
12. Repeat this process at least three to six times or until supernatant above the 10 cm mark is sufficiently clear. The number of times will depend on the clay percentage in the sample and how much material is needed. For this experiment, this process was repeated a minimum of six times before the supernatant above the 10 cm mark was sufficiently clear.

lvilvilvi

[2] To flocculate is to combine or cause [clay] particles to join together and fall out of the liquid to collect at the bottom of the jar.

13. Once an appropriate amount of clay has been collected, decant the supernatant in the clay jar as close to the clay collection as possible.
14. Transfer the clay to a centrifuge tube and centrifuge at 10,000 g (the acceleration is measured in multiples of "g," gravitational acceleration) for 1 minute to separate the particles from the liquid (see Figure 3.17).

Figure 3.17

Clay Tubes After Centrifuge Process has Separated Clay From the Water

15. Once the majority of the liquid has been removed, cover the tubes with cheesecloth or similar product, freeze in a freezer, and place in a freeze-dryer for approximately 12 to 36 hours. Evaporative cooling will keep the sample frozen until the last of the ice is sublimated. The sample will dry to a powdery consistency.
16. For this experiment, the clay was then removed from the tubes, weighed (grams) and placed in labeled containers.

After collecting the clay sample, the sand and silt can be separated.

17. After the final process of decanting of the clay sample, do not refill the soil jar with deionized water. Pour the sand and silt sediment into a 53-micron sieve, which will separate the particles. Thoroughly clean away the silt from the sand

with deonized water. The silt will flow through the sieve and collect in the bottom container and the sand will collect in the sieve.

18. Transfer the sand into a glass beaker, label the beaker and place in dry oven overnight at about 75°C.
19. Rinse out the soil jar with deionized water, relabel as the silt sample, and transfer the silt collected from the sieve into jar.
20. Add approximately 15 g calcium chloride ($CaCl_2$) to the silt sample and mix vigorously to initiate flocculation. Allow the silt sample to sit until the particles have settled to the bottom of the jar.
21. Once the silt has settled to the bottom of the jar, decant the supernatant as close to the silt collection as possible.
22. Transfer the silt to a centrifuge tube and centrifuge at 5,000 g for one minute to separate the particles from the liquid.
23. Once the majority of the liquid has been removed, cover the tubes with cheesecloth or similar product, freeze, and place in a freeze-dryer for approximately 12 to 36 hours. The sample will dry to a powdery consistency.
24. For this experiment, the silt was then removed from the tubes and the sand from the beakers, weighed (grams) and placed in labeled containers.

<u>Forest soil analysis.</u> Eighteen soil samples were sent to the UW Soil and Plant Analysis Lab, a branch of the UW Department of Soil Science in Madison, Wisconsin, for a forest soil analysis. The UW Soil and Plant Analysis Lab determined the measured amounts of potassium, calcium, magnesium, sodium, phosphorus, organic matter, pH, and total nitrogen within each sample. This analysis was intended to show the fertility of

the soil, which may relate to fire suppression and finally to the growth of the trees in the BWCAW.

Neutron Activation Analysis (NAA). Ten samples were sent to the University of Wisconsin Nuclear Reactor Laboratory (UWNR) for a NAA. Neutron activation analysis is a method of analysis of materials for the identification of elemental composition. The sample, which was either silt or fine sand, was irradiated with thermal neutrons, resulting in many of the constituent elements being activated. The activated products emit radiation or 'fingerprints' that are detected to determine the specific elements present. The amount of radiation given off is measured to indicate the amount of that element that is present in the sample. UWNR uses a technique, Instrumental Neutron Activation Analysis (INAA), in which gamma ray emissions are detected, which did not require chemical separations or special sample preparation. This test was done to obtain more information about the origin of the deeper soil strata and if there is a connection between the sediment at the Wendt site and glacial Lake Agassiz.

X-ray Diffraction (XRD). Two silt samples were sent to H & M Analytical Services in Allentown, New Jersey for an x-ray diffraction analysis. These silt samples were extracted from the original soil sample as a result of the particle separation test. The two silt samples sent were from Stratum 3 of Tree-Throw Unit 3 and Stratum 4 of Tree-Throw Unit 2. X-ray diffraction is a method used to compute an average particle size and size distribution in the 1-100 nanometer (nm) size range.

> "Each sample was put onto a zero background holder and loaded into a Bruker D4 diffractometer using Cu radiation at 40KV/40mA. Scans were run over the range of 10º - 90º with a step size of 0.02º and a counting time of 150 seconds per step. Once the diffraction patterns had been obtained, I identified the phases with the

> aid of the Powder Diffraction File (PDF) published by the International Centre for Diffraction Data…To help me in identifying the phases, I also ran a semi-quantitative chemical analysis by X-ray Fluorescence Spectroscopy to identify the major elements" [Dr. William E. Mayo, personal communication 2011].

This test was also used to detect elemental composition, especially rare earth elements, to obtain more information about the origin of the deeper soil strata and if there is a connection between the sediment at the Wendt site and glacial Lake Agassiz.

Phytolith analysis. Phytoliths, siliceous plant remains, contain carbon and are a useful piece of research used for reconstructing past vegetation in an area. Dating is possible with at least a 500-gram sample of soil to extract enough of the carbon to be dated (Mulholland 2011). Three samples were sent to the Duluth Archaeology Center to have the phytoliths analyzed for a paleoenvironmental reconstruction. These included Strata 2, 3 and 4 from Tree-Throw Unit 2.

Analytic Methods: Lithic Assemblage

Prehistoric lithic artifacts are known to have been made, used, reworked, and discarded at archaeological sites (Andrefsky 2005). The link between these lithic artifacts and the soil stratigraphy is an important connection to recognize. Analyzing lithic assemblages within a tree throw is important because if archaeologists are able to identify disturbed lithic material then they recognize that the stratigraphic context may have also been disturbed (Logan and Hill 2000). An archaeologist may still be able to interpret the human behavior responsible for the production, use, and maintenance of these lithic artifacts based on the use-wear seen on stone tools. However, determining human behavior based on the discard of those lithic artifacts or determining an approximate date may not be possible as a result of the disturbance. Because of this disturbance, an archaeologist may not be able to rely on the exact location of an artifact because it may have been moved by a form of turbation, such as tree throw in this instance. It would then be impossible to map the artifacts and designate specific areas of the site where one would have prepared meals or created stone technology. At the Wendt site, lithic artifacts were recovered from all strata including a sizeable grouping found on the surface of the colluvium in Tree-Throw Unit 3 (see Figure 3.18). For this research, the lithic analysis of the Wendt site material was conducted in the SCSU Archaeology Laboratory.

Figure 3.18

Lithic Artifacts in the Colluvium of Tree-Throw Unit 3

The lithic assemblage recovered from the three tree-throw units was initially cleaned and divided into sedimentary strata for analysis. The pieces were then organized into cultural and non-cultural categories based on a visual analysis. The non-cultural material was removed from the collection, which left a total of 935 lithic artifacts to analyze. Tree-Throw Unit 1 contained 156 lithic pieces, Tree-Throw Unit 2 contained 140 lithic pieces and Tree-Throw Unit 3 contained 639 lithic pieces. Each cultural artifact was then cataloged and labeled with a USFS code to ensure all pieces could be accounted for during and after the analysis. The maximum length, maximum width, maximum thickness, and weight were taken for each lithic artifact and organized into Excel spreadsheets to compute means and variances. A statistical analysis was conducted on maximum length, weight and volume of samples from specific sedimentary strata to more thoroughly understand patterning and variability that may have resulted from the effects of tree throw. The volume of each sample artifact was estimated as the product of maximum length, maximum width and maximum thickness, resulting in an approximate maximum volume and not an actual volume, because actual volume was not measured. A One-Way Analysis of Variance was run on each Thee-Throw Unit for all strata using a software statistical program called PAST (Obtained from http://folk.uio.no/ohammer/PAST/). After correcting for unequal variances among strata, a Tukey's range test for pairwise comparisons was done to estimate those pairs of strata that were significantly different at a significance level 0.05.

The various strata have different volumes so understanding artifact distribution will be more complete if both the number of artifacts per stratum and an estimate of the spacing of these artifacts are known. The area of each stratum was estimated from the profile scale drawings manually and the volume calculated by multiplying this area by the excavation width of 50 cm. I chose to use mean artifact spacing in a stratum rather than the number density of artifacts because the numbers are more meaningful to an archeologist. For number densities to be meaningful, a volume unit for the denominator must be meaningful; however, the appropriate standard scientific units of cm^3 or m^3 do not yield meaningful numbers and represent volumes that are too small or too large given the data collected. For example, a stratum with a mean artifact spacing of 10 cm, which is typical at the Wendt site, might have a density of 0.001 artifacts/cm^3 or 1000 artifacts/m^3; both numbers are not particularly intuitive to most archeologists compared to a mean spacing among objects of 10 cm.

Analytic Methods: Tree Samples

The analysis of the tree samples is important because they provide an approximate age of not only the excavation unit trees, but many of the trees within the vicinity. The samples also provided the possibility of identifying past burn scars from fires in the area.

Eleven stem core samples were taken in the field and brought back to the SCSU laboratory for analysis. The stem cores were photographed and analyzed under a microscope and the tree rings were counted to get an approximate age (see Figure 3.19). Unfortunately, a few samples broke apart during the difficult traveling process out of the BWCAW after the research trip had concluded. Those stem cores were also analyzed; however, the dates are approximate. It is also important to note that cross-dating to assign a single calendar year to a single ring was not performed on these samples since they were not sent to a tree-ring research lab. The stem cores were also analyzed under the microscope for past burn scar markings on the rings.

Figure 3.19

Stem Core Sample No. 3

Three tree-stem “cookie” samples were taken, one from each excavation unit at the site. Each tree-stem cookie was photographed and traced out on paper. A line was then drawn from the center of the tree out to the farthest edge. The distance from the center of the ring out to the edge was calculated by measuring each ring from the center (see Figure 3.20). As a result of the trees falling in 1999 and then burning in 2005, sections of the edges were slightly damaged; however, an approximate age could be determined.

Figure 3.20

Tree-Stem “Cookie” Sample from Tree-Throw Unit 2 with Radius Line

The methods used to analyze soil, cultural assemblages and tree samples discussed in this chapter are very diverse. Yet, these analyses make it possible to look at multiple facets of an archaeological site that, when combined, may relate to one another and give us a clear idea of what is happening in this dynamic system. In Chapter 4, the results of these methods will be discussed, including how they intermingle and what it might mean for future research in areas that have contained or currently contain tree throws.

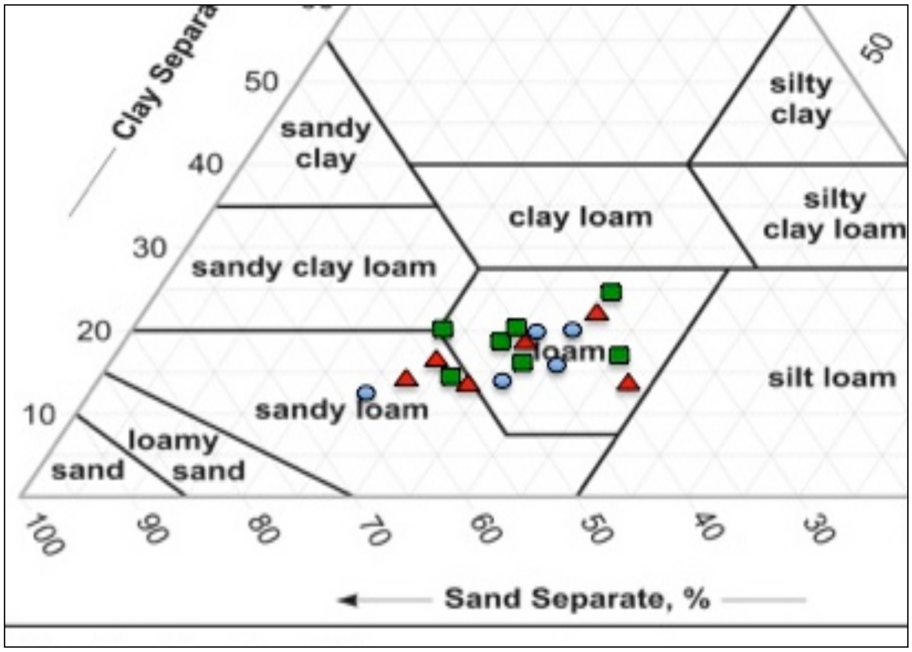
Chapter IV

RESULTS AND DISCUSSION

In this chapter, the results of this research will be discussed one characteristic at a time and organized by each excavation unit (tree-throw unit) in relation to those characteristics. The relevant characteristics are soil texture profiles, sand fractionation, forest soil analysis, particle separation and mineralogy, lithic analysis and tree characteristics. After the data are explained, the interpreted relationships among the different data will be discussed.

Soil Texture Profiles

The results of the soil texture analysis with the hydrometer method were informative in that they identified the soil texture of each stratum within the excavation unit, which may be a significant marker of tree throw for future excavators in the BWCAW. Figure 4.1 demonstrates the soil texture results from all three units at the Wendt site. The figure gives an idea of the range we see in the soil textures from unit to unit. This soil is generally a loam; however, some soils have more clay, some more silt and others are completely in the sandy loam textural class. The following sections will describe the results of each unit in more detail. See Figure 3.13 for the complete Soil Texture Triangle graphic. In two of the three units, the lower strata have higher amounts of sand and in all three units the highest sand content is found in the Colluvium.



Blue Circles = Tree-Throw Unit 1
Red Triangles = Tree-Throw Unit 2
Green Squares = Tree-Throw Unit 3

Figure 4.1

Hydrometer Results Displayed in the Soil Texture Triangle

Identifying soil texture, the degree of fineness or coarseness of the soil, is basically the percentage of sand, silt and clay in the soil (Eash et al. 2008). Soil textures are also indicative of the development and origin of the soils, which can be seen in the different strata of the soil profile. The development and possible origin of these soils will be addressed in more detail when the XRD and NAA test results are discussed. Soil texture can also indicate the presence of natural processes that may contribute to separation of particles by size; for example, the influence of water or wind on settling of soil particles of differing size and density.

Tree-Throw Unit 1. According to the hydrometer results for Tree-Throw Unit 1, the root system was growing in a loamy soil, which can also be seen in the loam designation for the potentially undisturbed regions of Strata 1 through 3 (see Table 4.1). A loam is simply a soil consisting of a significant amount of sand, silt, and clay. A simple loam with typical amounts of sand, silt or clay normally has about 20 percent clay, 40 percent silt, and 40 percent sand. Any excessive amount of sand, silt or clay will shift the textural class towards a specific class of loam such as a sandy loam (see Figure 3.13). In Tree-Throw Unit 1, the Colluvium was a sandy loam, which is demonstrated in the higher percentage of sand (see Table 4.1). This may result from wind dislodging soil particles with the larger and heavier sand particles falling into the pit while lighter clay and silt particles are blown away.

Table 4.1

Tree-Throw Unit 1: Hydrometer Test Results and Textural Class of Soil Strata

Flask ID	**Unit No.**	**Location**	**Soil Wt (g)**	**Percent Sand**	**Percent Clay**	**Percent Silt**	**Soil Texture (at 4 hours)**
H1	1	Roots	51.44	48%	14%	39%	Loam
H2	1	Colluvium	50.46	64%	10%	26%	Sandy Loam
H3	1	Stratum 1	50.35	42%	16%	42%	Loam
H4	1	Stratum 2	49.54	41%	20%	38%	Loam
H5	1	Stratum 3	50.42	44%	20%	36%	Loam

The soil profile in Figure 4.2 gives a clear perspective of where the textural designations are different in Tree-Throw Unit 1.

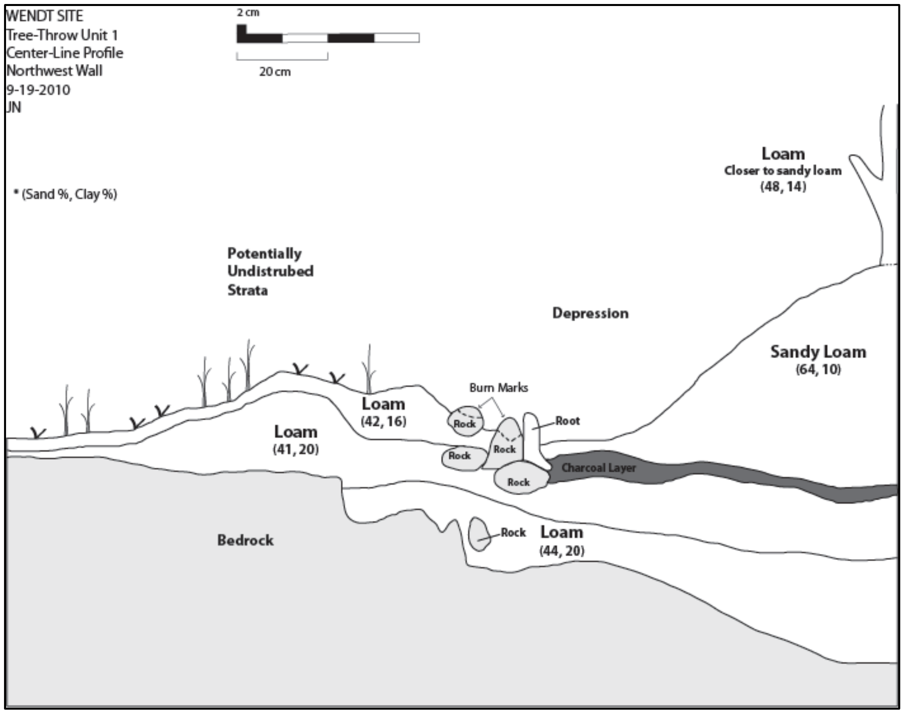


Figure 4.2

Tree-Throw Unit 1: Northwest Wall Soil Profile Identifying the Textural Classification of Strata

Tree-Throw Unit 2. The hydrometer results from Tree-Throw Unit 2 show slightly different results from Tree-Throw Unit 1. As seen in Tree-Throw Unit 1, the root system in Tree-Throw Unit 2 is also growing in a loamy soil; however, the lower strata show higher levels of sand, and were in turn designated sandy loams (see Table 4.2; Figure 4.3). When using soil textural designations, samples that contain amounts of sand, silt or clay that fall near a textural boundary may change textural designation with relatively small changes in particle size distribution. In the field, a "hand-texturing method" was used in Tree-Throw Unit 2 to determine the approximate texture of each stratum. This test consisted of rubbing moist soil between the thumb and forefinger to identify the stickiness and ability of the soil to ribbon through your fingers. This hand-texturing method requires a lot of experience and when these hand textures were compared with hydrometer results, none of the strata had the same texture identification, and discrepancies were one to two textural classes apart for Tree-Throw Unit 2. For example, in Stratum 3 of Tree-Throw Unit 2 the hand texture was silt loam and the hydrometer result was sandy loam (see Figure 3.13). This result suggests that hand texturing is not overly reliable unless the person doing the texturing is highly experienced in soil analysis.

Table 4.2

Tree-Throw Unit 2: Hydrometer Test Results and Textural Class of Soil Strata

Flask ID	Unit No.	Location	Soil Wt (g)	Percent Sand	Percent Clay	Percent Silt	Soil Texture (at 4 hours)
H6	2	Roots	49.41	45%	18%	36%	Loam
H7	2	Colluvium	49.64	52%	12%	36%	Sandy Loam/Loam
H8	2	Stratum 1	49.3	37%	16%	47%	Loam
H9	2	Stratum 2	49.34	37%	22%	41%	Loam
H13	2	Stratum 3	50.3	54%	16%	30%	Sandy Loam
H15	2	Stratum 4	50.19	58%	14%	28%	Sandy Loam

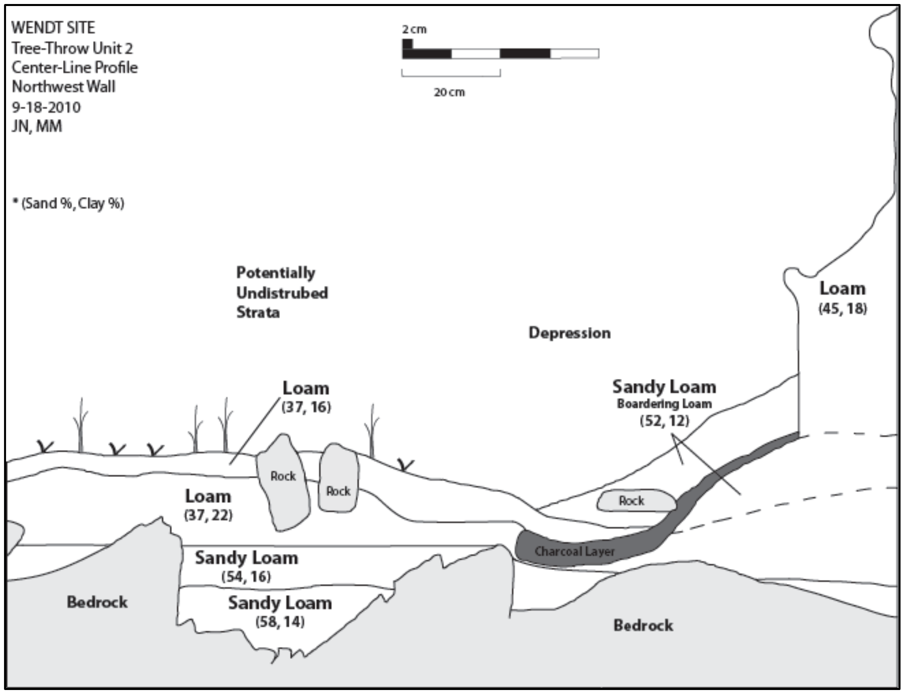


Figure 4.3

Tree-Throw Unit 2: Northwest Wall Soil Profile Identifying the Textural Classification of Strata

Tree-Throw Unit 2 was the only excavation unit that encountered a Stratum 4 level during this research at the Wendt site. In the case of Stratum 3 in Tree-Throw Unit 2, the sandy loam texture falls close to the loam-sandy loam boundary. The XRD and NAA analyses discussed later in this chapter will address the idea that Stratum 4 was potentially deposited from glacial Lake Agassiz, which has been evidenced over approximately 365,000 square miles in primarily Canada as well as North Dakota and Minnesota. The Colluvium also demonstrated higher levels of sand than the potentially undisturbed areas of Stratum 1 and Stratum 2.

<u>Tree-Throw Unit 3.</u> The hydrometer results from Tree-Throw Unit 3 show more similarities with Tree-Throw Unit 1 than with Tree-Throw Unit 2 in the potentially undisturbed strata. The sand content difference between root system samples and colluvium samples for Tree-Throw Unit 3 is less than that difference for Tree-Throw 1 and similar to that difference for Tree-throw 2; however, the colluvium sand percentages are consistently larger than the undisturbed strata for all three Tree-Throw units. The chart and figure below (Table 4.3; Figure 4.4) contain the textural results of Tree-Throw Unit 3 and the soil texture designation for each location.

Table 4.3

Tree-Throw Unit 3: Hydrometer Test Results and Textural Class of Soil Strata

Flask ID	Unit No.	Location	Soil Wt (g)	Percent Sand	Percent Clay	Percent Silt	Soil Texture (at 4 hours)
H18	3	Roots	50.91	51%	20%	29%	Loam
H10	3	Colluvium (Stratum 1)	50.62	47%	18%	36%	Loam
H17	3	Colluvium (Stratum 2)	50.94	53%	16%	31%	Sandy Loam
H16	3	Colluvium (Stratum 3)	49.43	45%	18%	36%	Loam
H12	3	Stratum 1	51.57	38%	17%	45%	Loam
H14	3	Stratum 2	50.83	35%	24%	41%	Loam
H11	3	Stratum 3	49.3	47%	16%	37%	Loam

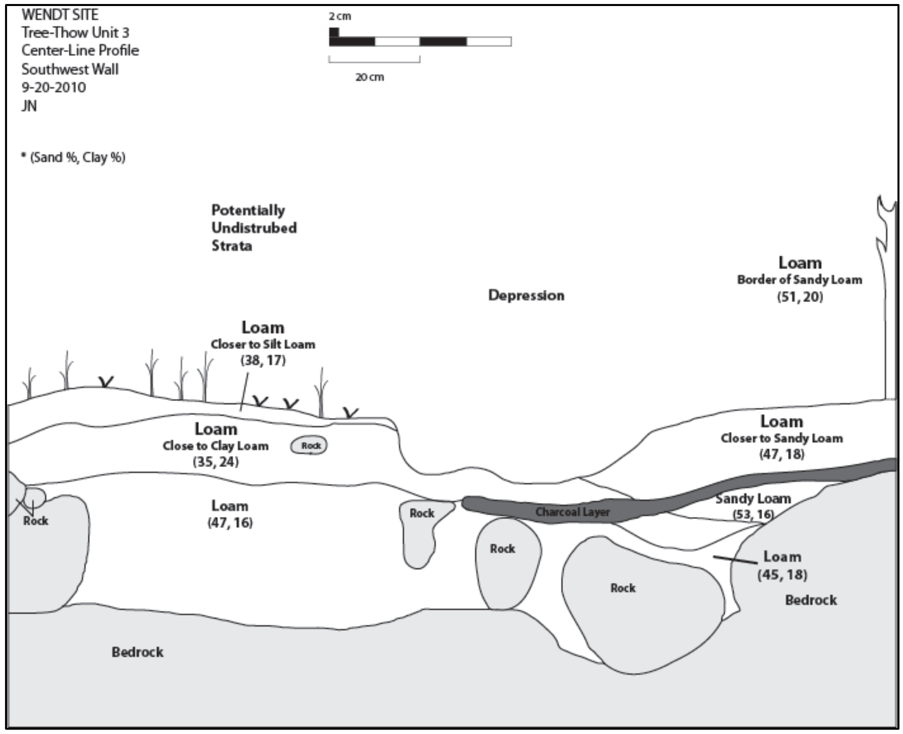


Figure 4.4

Tree-Throw Unit 3: Southwest Wall Soil Profile Identifying the Textural Classification of Strata

When the tree falls over pulling out the root system and exposing buried soil, through the action of wind, soil particles are dislodged; the larger particles of sand eventually fall back and collect in the pit or depression area and the fine particles of silt and clay may be carried away by the wind. Based on the soil data, this process is less evident for Tree-Throw Unit 3 than Tree-Throw Units 1 and 2. Several factors may contribute to variation in the sand accumulation in the pit: 1) If a heavy rain occurs soon after tree fall, the water may cause most of the soil on the root system to be washed into the pit with no enhancement of sand fraction, 2) the characteristics of the root system may influence the accumulation of larger particles in the pit, or 3) a particular uprooted tree base may be more sheltered from the wind so finer particles are not dislodged. In the case of Tree-Throw Unit 3, the root mass uplifted a smaller amount of soil so that it is possible that too little soil was removed in the uprooting to significantly increase the sand portion of the soil in the pit.

The idea is that once the tree decomposes and the pit fills in with soil and sediment, the soil will continue to show significantly more sandy textures in the upper levels where the root system would have been pulled out. The hydrometer test showed that there was not as high a percentage of sand in Strata 1 or 2 for any of the three excavation units compared to the disturbed areas (root system and colluvium).

Sand Fractionation Results

The sand fractionation test demonstrated the potential for the sand fraction of the soil to store water. Fine sand behaves more like silt, which is capable of storing more water than coarse sand. Coarse sand behaves more like gravel and offers very little water storage capability reducing tree growth potential. Trees have to grow on this stored water between rainfalls so fine sand improves growing conditions with respect to water availability.

In general, the sand fractionation results from all three Tree Throw units show that the sand grain size from 150 to 250 microns contains a lesser fraction of the total sand than any of the other size classes regardless of location. This may reflect the sorting process from its original location to its current location by wind or water. There is no obvious reason to expect that this result would have a significant impact on this research or archaeological sites in general. For future research, a larger sample size may show more definitive results (see Tables 4.4, 4.5 and 4.6). All the other size classes show comparable fractions of the total sand.

Table 4.4

Tree-Throw Unit 1: Sand Fractionation Sample Results

Percent of Total Sample	**Sample H1** Roots	**Sample H2** Colluvium	**Sample H3** Stratum 1	**Sample H4** Stratum 2	**Sample H5** Stratum 3
1 mm – 2 mm	15%	**25%**	**23%**	24%	23%
500 micron – 1 mm	21%	23%	22%	**25%**	**25%**
250 micron – 500 micron	23%	21%	22%	21%	21%
150 micron – 250 micron	14%	11%	13%	11%	11%
50 micron – 150 micron	**27%**	20%	20%	19%	20%

Table 4.5

Tree-Throw Unit 2: Sand Fractionation Sample Results

Percent of Total Sample	**Sample H6** Roots	**Sample H7** Colluvium	**Sample H8** Stratum 1	**Sample H9** Stratum 2	**Sample H13** Stratum 3	**Sample H15** Stratum 4
1 mm – 2 mm	22%	**25%**	21%	**28%**	**23%**	22%
500 micron – 1 mm	**25%**	24%	**23%**	25%	21%	19%
250 micron – 500 micron	23%	21%	**23%**	20%	21%	20%
150 micron – 250 micron	12%	11%	13%	10%	13%	13%
50 micron – 150 micron	18%	19%	20%	17%	22%	**26%**

Table 4.6

Tree-Throw Unit 3: Sand Fractionation Sample Results

Percent of Total	**Sample H18** Roots	**Sample H10** Colluvium S1	**Sample H17** Colluvium S2	**Sample H16** Colluvium S3	**Sample H12** Stratum 1	**Sample H14** Stratum 2	**Sample H11** Stratum 3
1 mm – 2 mm	19%	22%	18%	21%	21%	**24%**	**29%**
500 micron – 1 mm	22%	22%	22%	22%	20%	21%	20%
250 micron – 500 micron	22%	20%	**24%**	21%	22%	20%	19%
150 micron – 250 micron	14%	13%	14%	13%	13%	12%	11%
50 micron – 150 micron	**23%**	**23%**	22%	**23%**	**24%**	23%	21%

The presence of 30-40 percent of the sand at sizes less than 250 microns suggests that the fine sand portion of the sand fraction is not particularly high; thus water holding capacity of this sand fraction is likely to be minimal.

Forest Soil Analysis Results

The forest soil analysis tests, conducted by the University of Wisconsin Soil and Plant Analysis Lab, generated a thorough report of 18 samples broken down by element including: K (Potassium); Ca (Calcium); Mg (Magnesium); Na (Sodium); P (Phosphorus); Organic Matter; pH (measure of acidity in soil); and Total Nitrogen. This analysis showed that the soil in these tree-throw units is nutrient poor because much of the needed nutrients are tied up in the organic matter that is turning over at a slow rate. There is also a lot of variability in these results, which is expected for elements like Ca (Calcium) and Mg (Magnesium) (based on lab methods) and for K (Potassium) based on its movement in the environment. However, the variability seen in Na (Sodium) and P (Phosphorus) was somewhat surprising and may mean that some of the samples were slightly contaminated with organic material. The P (Phosphorus) results are very low, which may limit growth in this area, and the Na (Sodium) results are low, but not enough to cause a significant problem with growth. The Organic Matter results are high; however, this is not unusual for areas with significant conifer trees. According to Dr. Nick Balster, soils professor at the University of Wisconsin-Madison, the results for Total Nitrogen were also high; he usually sees numbers in the 0.07% (±0.02) range. It is possible that because the soil is nutrient poor showing low Phosphorus, moderate Sodium, low Magnesium and low Calcium levels that significant re-growth may not be happening. The trees in this area, such as the jack pines we analyzed, can grow in stressed soil; however, they grow very slowly and probably do not grow excessively tall or thick and most likely lack complex root systems. If this is the case, tree throw may not have been a critical issue at this site in recent years. Soil is a dynamic system, which makes it very hard to estimate what the soil nutrient concentrations would have been 10,000 years ago.

The following Table 4.7 details the results of these tests. The final measurements are grouped by location for better comparison between similar sections.

Table 4.7

Forest Soil Analysis Results Grouped by Tree-Throw Unit Location

Unit No.	Location	FSS Sample ID	K ppm	Ca ppm	Mg ppm	Na ppm	P ppm	Organic Matter %	pH	Total Nitrogen %
Root System										
1	Root System	FSS11	39.1	260.9	44.8	12.6	5.5	2.1	5.2	0.05
2	Root System	FSS12	98.6	304.0	47.2	15.5	5.6	3.9	4.7	0.11
3	Root System	FSS17	79.7	137.5	24.1	9.5	5.8	3.4	4.5	0.11
Colluvium										
1	Colluvium	FSS08	48.7	168.7	35.9	11.8	11.6	1.3	5.5	0.04
2	Colluvium	FSS16	91.1	352.8	58.9	12.2	6.6	2.3	5.1	0.07
3	Colluvium	FSS10	81.6	205.2	43.0	13.7	11.3	3.3	5	0.10
3	Colluvium-Stratum 2	FSS15	73.3	273.4	45.1	10.3	6.9	4.9	4.8	0.14
3	Colluvium-Stratum 3	FSS03	56.9	206.2	28.9	11.3	7.3	4.1	5.5	0.13
Stratum 1										
1	Stratum 1	FSS14	163.8	969.3	104.0	9.8	23.4	7.2	5.4	0.26
2	Stratum 1	FSS09	217.8	1301.2	190.1	10.5	68.7	11.6	4.8	0.46
3	Stratum 1	FSS06	178.6	845.3	135.8	9.1	35.1	7.5	4.5	0.29
Stratum 2										
1	Stratum 2	FSS05	50.4	310.8	44.6	9.8	6.5	4.8	5.2	0.13
2	Stratum 2	FSS01	52.8	406.4	46.9	11.3	9.3	6.6	5.3	0.18
3	Stratum 2	FSS13	38.2	171.4	26.8	10.8	4.9	2.8	4.7	0.09
Stratum 3										
1	Stratum 3	FSS18	46.3	286.2	48.5	11.7	6.8	3.8	5.1	0.12
2	Stratum 3	FSS02	35.2	330.4	47.8	17.4	12.5	2.4	4.7	0.05
3	Stratum 3	FSS04	37.5	329.0	40.9	15.9	6.9	3.3	4.9	0.09
Stratum 4										
2	Stratum 4	FSS07	28.1	135.5	21.8	13.3	17.7	1.3	5	0.05

This analysis suggests that the higher P (Phosphorus) concentration with lower concentrations of K (Potassium), Ca (Calcium), Mg (Magnesium), Na (Sodium) and organic matter content in Tree-Throw Unit 2 (Stratum 4), implies the possibility of

Stratum 4 having a different origin from strata 2 and 3 in all the units. I will follow this up with more discussion in the NAA section.

Particle Separation for Mineralogy and Elemental Results

Extracting clay from soil samples is a challenging endeavor and nearly impossible to do quantitatively; however, I was able to extract a small amount of clay from all but one sample. This test was conducted in order to have separated samples for additional tests to be conducted for this research as well as other current SCSU projects from the BWCAW. The fine sand was selected for the NAA element testing and the silt for the mineralogy tests (XRD and NAA) and the phytolith analysis. Of the 48 total soil samples separated in this process, eight were directly related to this research at the Wendt site. The other 40 were from other SCSU graduate students who collected samples from nearby sites.

A quick comparison of the texture estimates from the separation process reveals that only a fraction of the clay was actually separated out (Table 4.8). Some very fine clay is undoubtedly lost in the decanting process and some clay will also end up in the silt fraction because only a limited number of decantings is possible. However, the key here was to have enough clay and silt samples to do the mineralogy and phytolith analyses, which was accomplished. Another reason this test is not quantitative is that the initial soil weight was of a moist sample; however, the measure of moisture content is unknown.

Table 4.8

Final Weight of Sand, Silt and Clay Samples from the Particle Separation Process

Location	**Unit No.**	**Test #**	**Initial Soil Weight (g)**	**Final Clay Weight (g)**	**Final Silt Weight (g)**	**Final Sand Weight (g)**	**Final Sand Weight (g) after 2mm Sieve**
Stratum 4	2	[S] 32	70.04	2.18	23.94	38.51	36.81
Root System	3	[S] 33	70.21	1.34	26.59	37.50	36.90
Colluvium S1	3	[S] 01	179.00	3.63	43.18	86.63	58.47
Colluvium S2	3	[S] 35	70.46	1.83	26.81	34.74	34.31
Colluvium S3	3	[S] 22	70.30	1.71	25.93	34.10	33.30
Stratum 1	3	[S] 03	173.00	2.82	61.63	49.85	42.56
Stratum 2	3	[S] 34	70.11	2.30	30.26	28.20	27.74
Stratum 3	3	[S] 02	175.00	3.52	45.94	78.81	45.55

X-ray Diffraction (XRD) analysis results. Using X-ray Fluorescence (XRF), the samples were scanned sequentially for all elements between Na (Sodium) and U (Uranium); however, no rare earth elements were detected. These rare earth elements are either below the Limit of Detection (LOD) or not present in these samples. Table 4.9 details the results of the X-ray Fluorescence Spectroscopy analysis, which identified major minerals in the samples.

Table 4.9

X-ray Fluorescence Spectroscopy Results, a Semi-Quantitative Mineral Analysis

Major Minerals	Unit 3, Stratum 3 Sample #02 ppm	Unit 2, Stratum 4 Sample #32 ppm
Na2O	1.72	1.89
MgO	1.96	1.88
Al_2O_3	17	14.9
SiO_2	62.52	61.72
P_2O_5	0.2	-
Cl	-	0.57
K_2O	2.22	2.52
CaO	2.47	3.54
TiO_2	1.05	1.01
Cr_2O_3	0.031	0.04
MnO	0.08	0.09
Fe_2O_3	10.61	11.69
CuO	0.02	0.04
ZnO	0.03	0.02
SrO	0.04	0.09
ZrO_2	0.03	0.03

Minerals not listed are below their respective Limit Of Detection

In addition to the elements between Na (Sodium) and U (Uranium), Dr. William Mayo, chief scientist at H & M Analytical Services, Inc., added O (Oxygen), H (Hydrogen), and C (Carbon) to the search matrix for the crystalline phase identification of the minerals. Dr. Mayo identified all of the major phases and most of the minor and trace phases with good confidence. The analysis is summarized below (see Table 4.10).

Table 4.10

Semi-Quantitative Phase Identification Analysis

	Unit 3, Stratum 3 Sample #02 wt %	Unit 2, Stratum 4 Sample #32 wt %
SiO_2 (Quartz)	44.6	37.7
$Na(AlSi_3O_8)$ (Albite)	23.3	27.7
$Fe_2(SiO_4)$ (Fayalite)	4.0	0.5
$K(AlSi_3O_8)$ (Microcline)	10.6	14.3
$(Mg_2Al)(AlSiO_5)(OH)_4$ (Amesite)	4.1	7.1
$NaCa(Mg,Fe)_4Al(Si_6Al_2)O_{22}(OH, Cl)_2$ ((Ferro)Pargasite)	4.3	5.7
$KAl_2(AlSi_3O_{10})(OH)_2$ (Muscovite)	8.0	5.1
$(Fe,Ca)(SiO_3)_2$ (Clinopyroxene)	1.1	1.9

The final XRD analysis results are inconclusive at this time because of the limited amount of samples analyzed and the additional, comparative research needed to discuss their importance. For further reference, the experimental XRD patterns and exploded views of the analysis are shown in the attached Appendix A.

Neutron Activation Analysis (NAA) elemental results. Tree-Throw Unit 2 is the only unit with a Stratum 4 and based on the Forest Soil Analysis, more exploration of possible differences between Stratum 4 and Strata 2 and 3 were explored with the NAA (see Appendix B for detailed data). Notable differences occurred with the following elements: Au (Gold), Zr (Zirconium), Ba (Barium), Br (Bromine), Dy (Dysprosium), Nd (Neodymium) and Sm (Samarium), with Dy, Nd and Sm being rare-earth elements (see Table 4.11).

Table 4.11

Element Differences Between Stratum 4 and Strata 2 and 3 in Tree-Throw Unit 2

Strata	**Au**	**Zr**	**Ba**	**Br**	**Dy**	**Nd**	**Sm**
2	**X**	**X**	ND	ND	**X**	ND	**X**
3	**X**	**X**	**X**	**X**	ND	**X**	ND
4	ND	ND	**X**	ND	ND	ND	ND

X indicates that the element was detected by NAA
ND indicates that the element was not detected by NAA

Stratum 4 appears to be different from Strata 2 and 3 in Tree-Throw Unit 2; however, identifying the origin requires further analysis of various sources. Although Stratum 4 was not identified in Tree-Throw Unit 1 or 3, Strata 2 and 3 were observed. Samples from Tree-Throw Units 1 and 3 did not contain Au or Br, but they did contain Zr, Dy, Nd and Sm. Therefore, the elements detected in Strata 2 and 3 of Tree-Throw Unit 2 are largely consistent with Strata 2 and 3 in Tree-Throw Units 1 and 3.

Hopefully this NAA data will be useful for identifying the source regions of soil materials in this area when more data are available.

Phytolith analysis results. Dr. Susan C. Mulholland, president and principal investigator at the Duluth Archaeology Center in Duluth, Minnesota, conducted the phytolith analysis with previously separated soil samples (Mulholland 2011). Mulholland looked at three samples from the Wendt site in Tree-Throw Unit 2 including Strata 2, 3 and 4. It was discovered that phytoliths were common to abundant only in

Stratum 2. Different types of grasses dominated Stratum 2 including Panicoids and Chloridoids, with Pooids still a dominant type yet proportionately less (see Table 4.12).

Table 4.12

Phytolith Data* for the Wendt Site

Sample No.	Location	Abundance	Assemblage	Grass Types
10	Unit 2, Stratum 2	Common/Abundant	Grass (65%)	Rondels (38%)/Saddles (26%)/Dumbbells (27%)
12	Unit 2, Stratum 3	Rare	Not Counted	Not Counted
11	Unit 2, Stratum 4	Rare	Not Counted	Not Counted

*Data from Phytolith Analysis of Sediments From Three Sites, Knife Lake, Minnesota report, 2011

In Strata 3 and 4, rare to occasional phytoliths were observed; however, the difference between Stratum 2 and the lower levels of Strata 3 and 4 was abrupt and not gradual (Mulholland 2011). It is clear that phytolith-producing plants contributed to Stratum 2; although, it is unknown whether their origin was natural or cultural. In Strata 3 and 4, there was no plant material contributors, no phytolith-producing plant contributors present or a possible post-depositional process that destroyed phytoliths in these levels. According to Dr. Mulholland (2011), the distinct difference between Stratum 2 and Strata 3 and 4 may reflect the fact that these latter samples were from a tree throw. It also suggests that later plant contributions to the site were more diverse in the types of grass species than earlier sediment layers. However, more research is needed to validate these findings.

Lithic Artifact Assemblage Analysis Results

One of the most valuable links we see in the lithic artifact assemblage analysis is the connection between the artifact groupings and the soil stratigraphy. Analyzing lithic artifact assemblages within a tree throw is important for the following reason: if archaeologists are able to identify disturbed lithic artifacts, then they may recognize that the stratigraphic context may also have been disturbed (Logan and Hill 2000). At the Wendt site, lithic artifacts were recovered from all strata in each unit including a sizeable grouping found on the surface and below the surface of the colluvium in Tree-Throw Unit 3.

After analyzing the lithic assemblages to discern whether each piece was cultural or noncultural, the confirmed cultural artifacts were grouped and labeled by their location. The percentage by unit-strata, based on the total number of pieces per unit, was calculated, and these percentages were included on the soil-profile figures for each unit to show similarities and differences among the three tree-throw units (see Figures 4.5, 4.6, and 4.7).

Tree-Throw Unit 1. A total of 148 artifacts were identified in Tree-Throw Unit 1 with both the potentially undisturbed area and the disturbed areas of the Root System and Colluvium almost split evenly with each having approximately 50 percent of the total artifacts (see Figure 4.5). However, when analyzing each stratum, the Colluvium percentage is somewhat higher at 37.2 percent even though the mean artifact spacing is similar among all strata except Stratum 3, which is much lower than the others (see Table 4.13). It is also interesting to note that Stratum 2 also contained a large number of artifacts with 28.4 percent of the total.

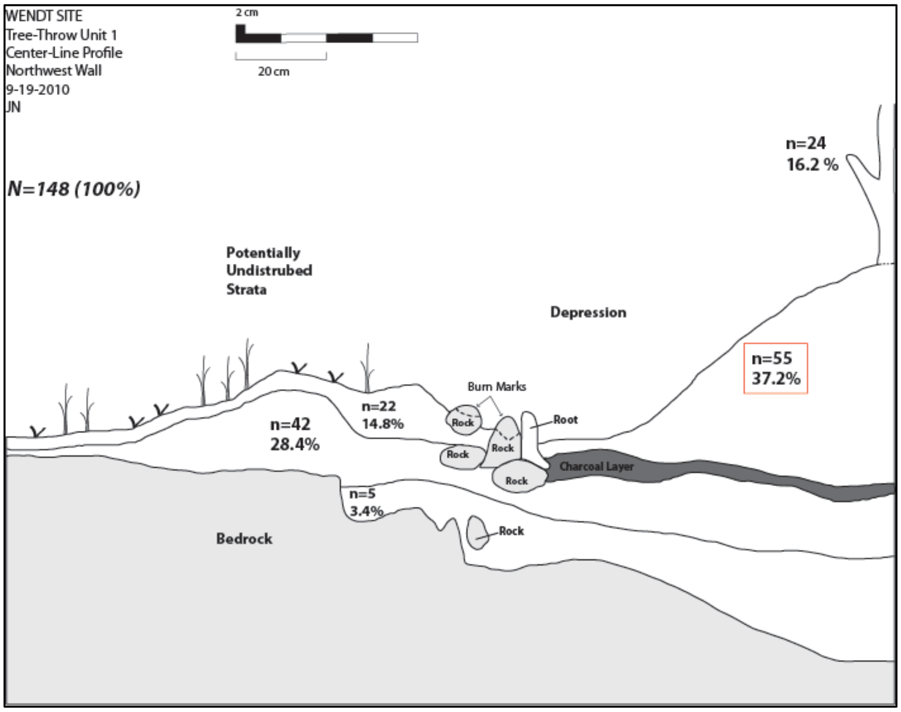


Figure 4.5

Lithic Assemblage Percentages in Tree-Throw Unit 1

Table 4.13

Artifact-Spacing Distribution by Strata in Tree-Throw Unit 1

Strata	Unit No.	Number of Artifacts	Volume (cm^3)	Spacing (cm/artifact)
Stratum 1	1	22	43600	12.6
Stratum 2	1	42	102400	13.5
Stratum 3	1	5	78800	25.1
Colluvium	1	55	86200	11.6

Tree-Throw Unit 2. As identified in Tree-Throw Unit 1, Tree-Throw Unit 2 showed a number of similarities in the patterning even though four strata were observed in Tree-Throw Unit 2. Tree-Throw Unit 2 had a slightly smaller total number of artifacts at 140, yet the largest percentage was also found in the Colluvium at 39.3 percent and had the smallest mean spacing among artifacts (see Figure 4.6 and Table 4.14). This is the same pattern seen in Tree-Throw Unit 1.

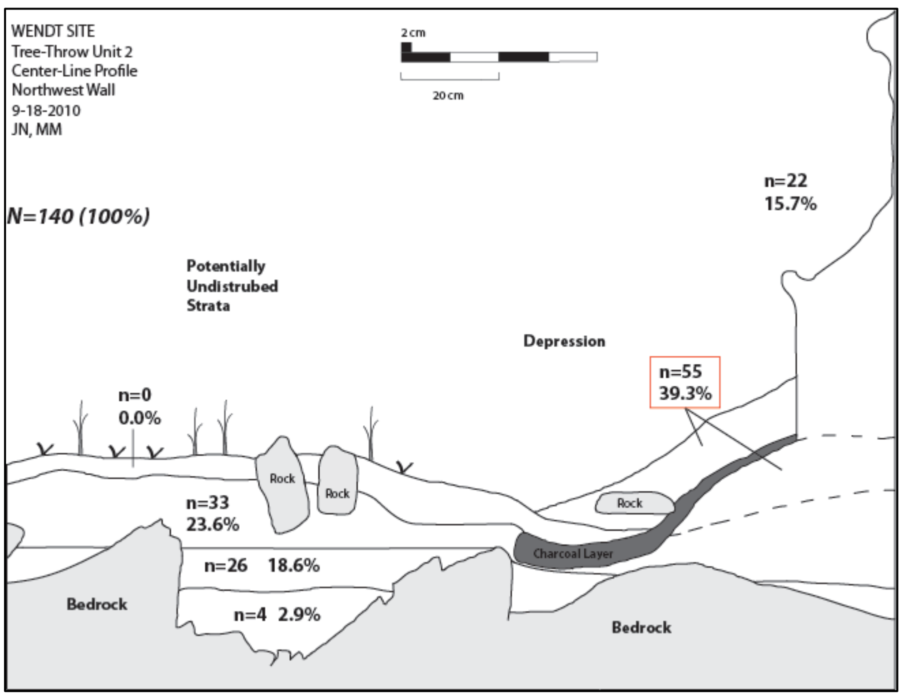


Figure 4.6

Lithic Assemblage Percentages in Tree-Throw Unit 2

Table 4.14

Artifact-Spacing Distribution by Strata in Tree-Throw Unit 2

Strata	**Unit No.**	**Number of Artifacts**	**Volume (cm^3)**	**Spacing (cm/artifact)**
Stratum 1	2	0	0	0
Stratum 2	2	33	30000	9.7
Stratum 3	2	26	88600	15.0
Stratum 4	2	4	32800	20.2
Colluvium	2	55	44000	9.3

As also seen in Tree-Throw Unit 1, Stratum 2 in Tree-Throw Unit 2 contained the largest number of artifacts in the potentially undisturbed area with 23.6 percent. Additional similarities include the lowest level in both units having a very small percentage (Tree-Throw Unit 1 (Stratum 3) with 3.4 percent and Tree-Throw Unit 2 (Stratum 4) with 2.9 percent) and large mean artifact spacing. The Root System had almost the same percentage in both units (Tree-Throw Unit 1 with 16.2 percent and Tree-Throw Unit 2 with 15.7 percent). It is possible that when the tree stem fell and the root system was pulled out of the ground that the lithic artifacts were pulled out, mainly from Stratum 2, and up into the uplifted root system. Eventually, those artifacts, along with disturbed soil, fell back into the colluvium area where they collected in higher numbers when mixed with artifacts from other levels. Along with this we see that the Colluvium in both Tree-Throw Unit 1 and Tree-Throw Unit 2 are sandy loams, which may be a visual or textural hint that a tree throw has occurred. The top two levels were probably loams and when they were pulled up they collected on the upturned root system. The lighter particles (clay and silt) may have been moved by wind or adhered more tightly to the root system so that particles which fell back into the Colluvium gave the Colluvium a coarser texture.

Tree-Throw Unit 3. When the lithic artifacts in Tree-Throw Unit 3 were grouped by strata, a significant aspect was identified. This unit has more artifacts per unit volume compared to Tree-Throw Units 1 and 2 (see Table 4.15). Of the 639 lithic artifacts, 447 of them (70 percent) were located in the Colluvium (see Figure 4.7). As previously noted, the Colluvium in this unit was broken down into three sections including the Colluvium at the base of the roots, Colluvium (Stratum 2), and Colluvium (Stratum 3).

Table 4.15

Artifact-Spacing Distribution by Strata in Tree-Throw Unit 3

Strata	**Unit No.**	**Number of Artifacts**	**Volume (cm^3)**	**Spacing (cm/artifact)**
Stratum 1	3	21	11600	8.2
Stratum 2	3	18	48600	13.9
Stratum 3	3	35	101200	14.2
Colluvium	3	237	41000	5.6
Colluvium S2	3	37	7400	5.8
Colluvium S3	3	173	19400	4.8
Depression S2	3	24	18400	9.2
Depression S3	3	34	18000	8.1

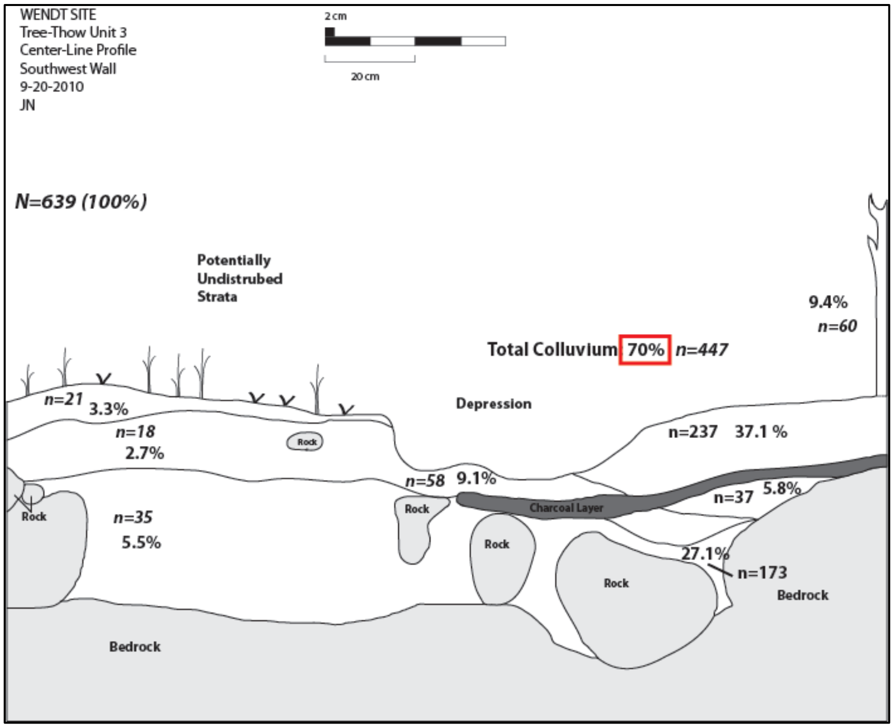


Figure 4.7

Lithic Assemblage Percentages in Tree-Throw Unit 3

One pattern seen in both Tree-Throw Unit 1 and Tree-Throw Unit 2 is also seen in Tree-Throw Unit 3; namely, the Colluvium contained more lithic artifacts than the undisturbed strata, and mean artifact spacings were smallest in the Colluvium regions. This pattern, which represents a higher number density of artifacts in the Colluvium, might suggest that when a tree throw occurs, the lithic artifacts are pulled out of the ground or from the surface and later deposited with disturbed soil within the open depression area — much of which becomes the Colluvium. This may point to the reason why we see a larger concentration of lithic artifacts in the Colluvium area of each unit.

Interestingly, based on the total assemblage in Tree-Throw Unit 3, the Colluvium at the base of the roots contained 37.1 percent, the Colluvium (Stratum 2) contained 5.8

percent, and the Colluvium (Stratum 3) contained 27.1 percent of the lithic artifacts collected, but the mean artifact spacings are all similar. Although, Colluvium (Stratum 2) has a small volume of soil, it contains the largest artifacts in Tree-Throw Unit 3. Not only is the 27.1 percent a surprising number in Colluvium (Stratum 3), but also lithic artifact discovery was documented all the way through this level to bedrock. Additionally, the Colluvium (Stratum 3) in Tree-Throw Unit 3 is a loam as opposed to a sandy loam as we see above this level (see Figure 4.4). It is possible that the Colluvium (Stratum 3) is potentially a layer that was not affected by the current tree throw, but a former tree throw. According to D.A. Norton (1988), the tendency for trees to reestablish on mounds of previous tree throws is common in forested regions. It is possible that the current tree throw pulled up the Stratum 2 that is now replaced by Colluvium (Stratum 2) while leaving the stratum nearest bedrock (labeled Colluvium (Stratum 3)) unaffected; which might be why we see a high concentration of artifacts at such a low depth compared to Stratum 2. However, it is possible that the root system in this unit went to bedrock and when the tree throw occurred, the lower level was filled with the just-uprooted material, which would be loamy. It is difficult to confirm how far the roots may have descended because they were severely burned in the USFS prescribed burn in 2005. Although, when combined with the forest soil results that point to slow or limited growth of the trees in this area, it would seem unlikely that the root system went to bedrock.

Statistical and Artifact Size-Grade Analysis.

Statistical analysis. A one-way ANOVA was conducted to determine if there was a significant difference among artifact characteristics in the different strata and units. This statistical analysis of the lithic artifacts showed mixed results (see Tables 4.16, 4.17, 4.18). The length had the most significant differences among strata, the weight showed slightly less and the volume (defined as maximum length times maximum width times maximum thickness) showed no differences in Tree-Throw Unit 1 and 2, with only the Colluvium showing significant differences in volume compared with all other strata in Tree-Throw Unit 3.

Table 4.16

Results of a One-Way ANOVA Analyzing Maximum Artifact Length (shaded boxes are significantly different at 95% confidence interval)

Unit 1 Length					
	Str. 1	Str. 2	Str. 3	Root	Colluvium
Str. 1		0.3456	0.007433	0.9996	0.008376
Str. 2			1.90E-05	0.2389	0.5893
Str. 3				0.0149	1.72E-05
Root					0.004021
Colluv.					

Unit 2 Length					
	Str. 1	Str. 2	Str. 3/4	Root	Colluvium
Str. 1	-	-	-	-	-
Str. 2			0.9636	0.2823	0.0247
Str. 3/4				0.1073	0.08878
Root					3.142E-05
Colluv.					

Unit 3 Length							
	Str. 1	Str. 2	Str. 3	Root	Colluvium	Colluvium.2	Colluvium.3
Str. 1		0.9919	0.9518	0.004109	2.569E-05	0.2557	2.569E-05
Str. 2			0.6004	0.0002274	2.569E-05	0.04452	2.569E-05
Str. 3				0.1017	2.569E-05	0.8679	2.569E-05
Root					2.569E-05	0.7908	2.569E-05
Colluv.						2.569E-05	2.569E-05
Colluv.2							2.569E-05
Colluv.3							

Table 4.17

Results of a One-Way ANOVA Analyzing Maximum Artifact Volume (shaded boxes are significantly different at 95% confidence interval)

Unit 1 Volume					
	Str. 1	Str. 2	Str. 3	Root	Colluvium
Str. 1		1	0.9949	0.8552	0.7884
Str. 2			0.9963	0.8407	0.7711
Str. 3				0.6312	0.5441
Root					0.9999
Colluv.					

Unit 2 Volume					
	Str. 1	Str. 2	Str. 3/4	Root	Colluvium
Str. 1	-	-	-	-	-
Str. 2			0.9654	0.9946	0.5751
Str. 3/4				0.889	0.8499
Root					0.4193
Colluv.					

Unit 3 Volume							
	Str. 1	Str. 2	Str. 3	Root	Colluvium	Colluvium.2	Colluvium.3
Str. 1		1	1	0.502	2.619E-05	0.9158	0.4791
Str. 2			0.9998	0.4126	2.591E-05	0.8635	0.3911
Str. 3				0.6631	2.777E-05	0.9724	0.6406
Root					0.004737	0.9909	1
Colluv.						0.0002495	0.005373
Colluv.2							0.9884
Colluv.3							

Table 4.18

Results of a One-Way ANOVA Analyzing Maximum Artifact Weight (shaded boxes are significantly different at 95% confidence interval)

Unit 1 Weight					
	Str. 1	Str. 2	Str. 3	Root	Colluvium
Str. 1		0.9999	0.4258	0.9816	0.7352
Str. 2			0.3474	0.9597	0.8091
Str. 3				0.7741	0.02713
Root					0.385
Colluv.					

Unit 2 Weight					
	Str. 1	Str. 2	Str. 3/4	Root	Colluvium
Str. 1	-	-	-	-	-
Str. 2			0.7074	0.5917	0.03052
Str. 3/4				0.0922	0.3356
Root					0.0003874
Colluv.					

Unit 3 Weight							
	Str. 1	Str. 2	Str. 3	Root	Colluvium	Colluvium.2	Colluvium.3
Str. 1		0.8551	0.9783	0.02509	9.897E-05	1	0.9939
Str. 2			0.9995	0.0001772	2.573E-05	0.8006	0.4336
Str. 3				0.001076	2.636E-05	0.9607	0.7227
Root					0.7774	0.03516	0.1592
Colluv.						0.0001499	0.001563
Colluv.2							0.9977
Colluv.3							

Analyzing the maximum artifact length, in Tree-Throw Unit 1, we saw significant differences between the Colluvium (22.7 mm) and Strata 1 (31 mm), 3 (21.5 mm) and the Root System (26.9 mm) as well as between Stratum 3 (21.5 mm) and Strata 1 (31 mm), 2 (23.8 mm), the Root System (26.9 mm). In Tree-Throw Unit 2, we only saw a significant difference between the Colluvium (22.5 mm) and the levels of Stratum 2 (23.4 mm) and the Root System (21.7 mm). Finally, in Tree-Throw Unit 3, the Colluvium (Stratum 3) (23.7 mm) was significantly different from all other strata, Colluvium (Stratum 2) (39.6 mm) was also significantly different from Stratum 2 (28.5 mm), and the Colluvium (29 mm) was significantly different from Strata 1 (35.2 mm), 2 (28.5 mm), 3 (30.4 mm) and the Root System (32 mm).

When analyzing the weight, we see fewer differences among the strata in Tree-Throw Unit 1. In Tree-Throw Unit 1, the Colluvium (11.3 g) was significantly different from Stratum 3 (1.1 g). In Tree-Throw Unit 2, the Colluvium (7.7 g) was significantly different from Stratum 2 (1.9 g) and the Root System (1.6 g). In Tree-Throw Unit 3, the Colluvium (7.0 g) was significantly different from Strata 1 (8.4 g), 2 (7.6 g), 3 (7.1 g), Colluvium (Stratum 2) (13.5 g), and Colluvium (Stratum 3) (3.7 g); furthermore, the Root System (12.5 g) was significantly different from Strata 1 (8.4 g), 2 (7.6 g), 3 (7.1 g), and Colluvium (Stratum 2) (13.5 g).

Artifact size-grade analysis. Analyzing the distribution of cultural artifacts by length, width, thickness and weight could potentially tell us something about the site formation processes happening at the Wendt site. If we assume that the action of gravity on the largest artifacts means that they will be deposited from the up-rooted tree first, the redistribution of objects following the tree throw should show that heaver/larger artifacts end up lower in the Colluvium layers and the lighter/smaller artifacts will be higher up. Table 4.19 below shows the calculated means for maximum artifact length, width, thickness and weight organized by unit.

Table 4.19

Calculated Mean for Length, Width, Thickness, and Weight

Unit #	Location	Max Length (mm)	Max Width (mm)	Max Thickness (mm)	Weight (g)	No. of Artifacts
Unit 1	Colluvium	22.7	15.5	6.2	11.3	55
Unit 1	Root System	26.9	17.7	6.4	**25.1**	24
Unit 1	Stratum 1	**31.0***	**20.1**	**7.0**	6.2	22
Unit 1	Stratum 2	23.8	14.6	6.2	3.5	42
Unit 1	Stratum 3	21.5	13.4	5.3	1.1	5
Unit 2	Colluvium	22.5	14.2	4.2	7.7	55
Unit 2	Root System	21.7	14.9	3.9	1.6	22
Unit 2	Stratum 2	23.4	14.2	3.9	1.9	33
Unit 2	Stratum 3	27.7	19.5	7.9	**8.5**	26
Unit 2	Stratum 4	**33.0**	**20.7**	**9.5**	6.3	4
Unit 3	Colluvium	29.0	18.7	5.6	7.0	237
Unit 3	Colluvium-Stratum 2	**39.6**	**24.5**	**8.0**	**13.5**	37
Unit 3	Colluvium-Stratum 3	23.7	15.2	4.5	3.7	173
Unit 3	Depression-Stratum 2	23.5	16.0	3.9	2.9	24
Unit 3	Depression-Stratum 3	26.8	17.2	5.1	3.8	34
Unit 3	Root System	32.0	21.5	5.5	12.5	60
Unit 3	Stratum 1	35.2	22.4	6.8	8.4	21
Unit 3	Stratum 2	28.5	18.2	6.1	7.6	18
Unit 3	Stratum 3	30.4	18.8	4.7	7.1	35

*The maximum values in each stratum are in bold

In Tree Throw Unit 1, Stratum 1 (22 artifacts identified) had the highest mean for length (31.0 mm), width (20.1 mm) and thickness (7.0 mm); however, the Root System had the highest mean weight (25.1 g) (see Figure 4.8). In Tree Throw Unit 2, Stratum 4 (4 artifacts identified) had the highest mean for length (33.0 mm), width (20.7 mm) and thickness (9.5 mm); however, Stratum 3 had the highest mean weight (8.5 g) (see Figure 4.9). It is possible that cryoturbation, which occurs when repeated freezing and thawing causes disturbances in the soil and in turn archaeological remains, played a role in reorganizing these artifacts stratigraphically by size/weight class without the assistance of tree throw (Waters 1992). Cryoturbation can play a major role in northern Minnesota site formation processes, and tends to move the largest artifacts upward in the soil profile more quickly than smaller artifacts (Waters 1992). In Tree-Throw 1, the Root System had a single artifact that was 120 times the weight of the mean of the other 23 artifacts; after removing this outlier the mean of the other 23 artifacts is 4.1 g, which is less than the mean weight of artifacts in Stratum 1. Furthermore, the Colluvium also contains a single artifact that is 85 times the weight of the mean of the other 54 artifacts and removing this extreme outlier results in a mean of 4.5 g, which also is less than the mean weight of artifacts in Stratum 1. Thus, except for two artifacts, all artifact measures are at maximum values in Stratum 1. This is consistent with the effects of cryoturbation.

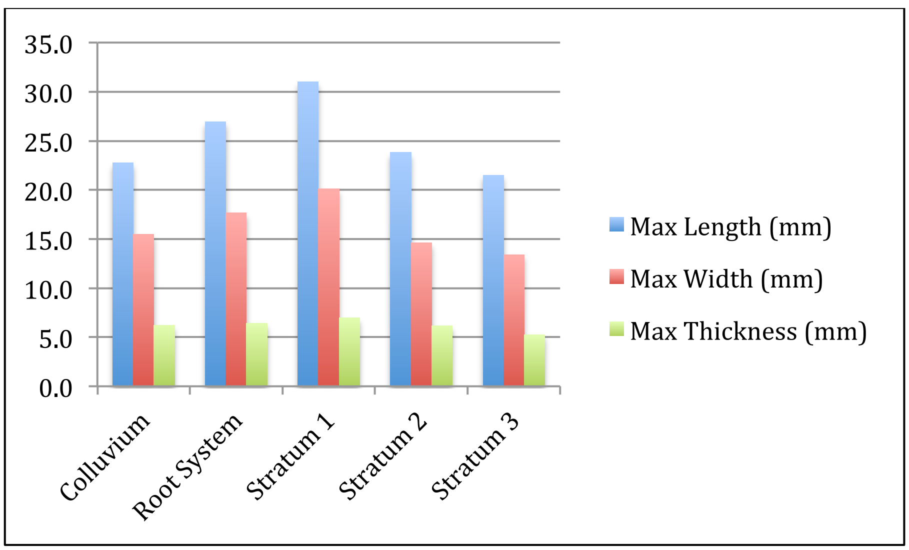


Figure 4.8

Bar Graph of Tree-Throw Unit 1 Averages of
the Max Length, Width, and Thickness

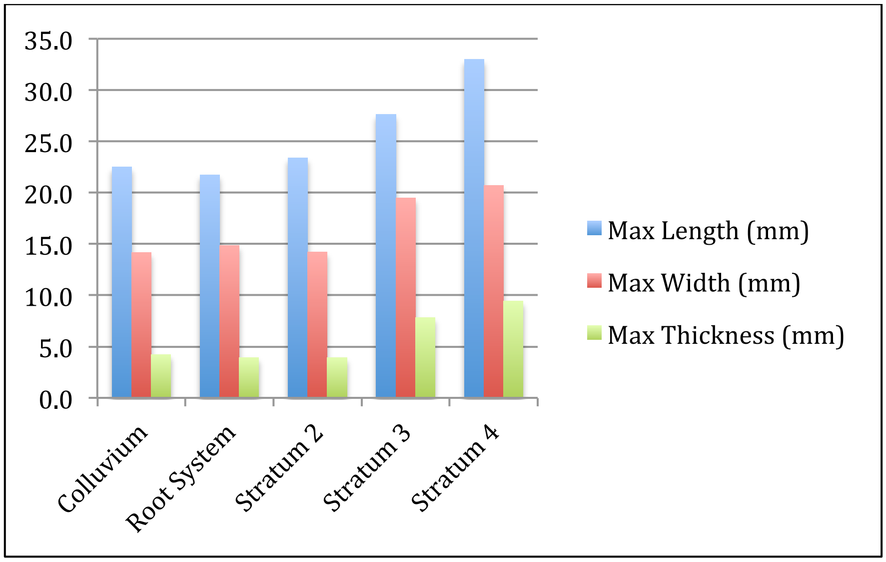


Figure 4.9

Bar Graph of Tree-Throw Unit 2 Averages of
the Max Length, Width, and Thickness

In Tree-Throw 2, a single artifact in Stratum 3 is 20 times heavier than the mean of the other 25 artifacts (8.5 g) and if this single outlier is removed, the largest mean weight is then in the Colluvium (7.7 g). No obvious explanation for this occurrence of the largest artifacts in the deepest layer is apparent.

Technically, Tree-Throw Units 1 and 2 are not suitable for determining if the largest artifacts were deposited first because only a single Colluvium layer was excavated. This resulted because of time and labor constraints during the excavations. In Tree Throw Unit 3, the Colluvium (Stratum 2) (37 artifacts identified) had the highest mean in all of the categories. The beginning of an explanation for the occurrence of the largest artifacts in Colluvium (Stratum 2) was given the section above titled " Lithic Artifact Assemblage Analysis Results" under "Tree-Throw Unit 3"; which suggested that the uprooting penetrated only as deep as Colluvium (Stratum 2). Thus the larger, heavier objects collected in Colluvium (Stratum 2) until the prescribed burn took place and laid down a layer of charcoal. After the burn, the artifacts and soil continued to fall from the root system creating the upper Colluvium level. We might suggest that the Colluvium (Stratum 3) layer was more similar to the undisturbed Strata 2 and 3 levels; after all, the number and size of artifacts in Colluvium (Stratum 3) appear more similar to Stratum 2 and/or Stratum 3 than Colluvium (Stratum 2). Presumably the presence of a tree-throw event sometime in the past might leave a layer of relatively few, large-size artifacts somewhere in the depth of the profile depending on the size and depth of the up-rooted trees. This is a presumption for which we have relatively weak evidence. With this interpretation, the results from Tree-Throw Unit 3 do support the hypothesis that larger artifacts will be deposited first from the exposed uprooted tree.

From Figure 4.10, the second longest artifacts occur in Stratum 1, which is consistent with the expected effect of cryoturbation. Thus, Tree-Throw Units 1 and 3 support the occurrence of cryoturbation, but Tree-Throw Unit 2 does not have any artifacts in Stratum 1; an unusual situation for this site.

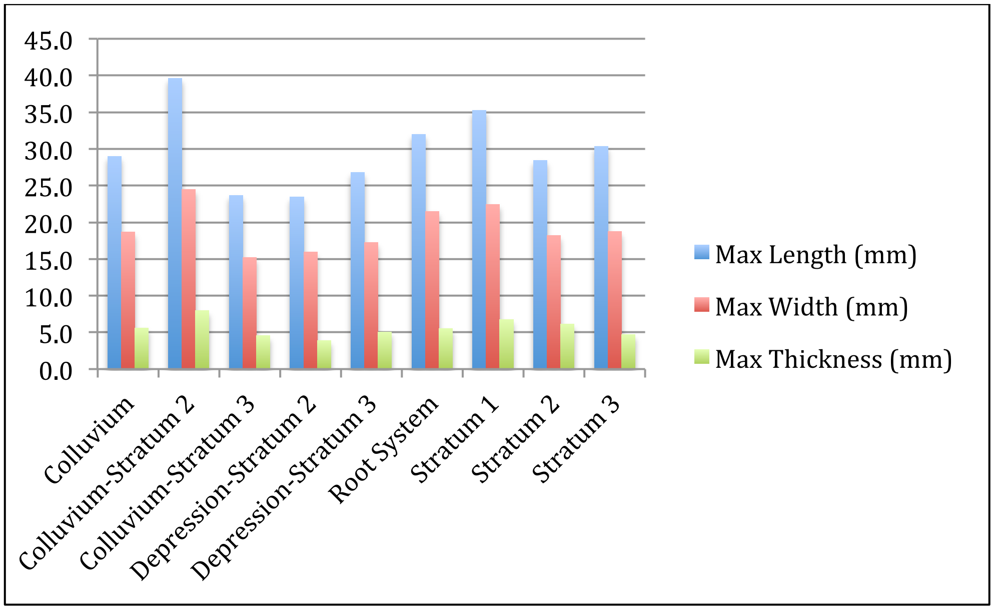


Figure 4.10

Bar Graph of Tree-Throw Unit 3 Averages of
the Max Length, Width, and Thickness

Tree Stem Analysis Results

Twelve stem-core samples, 11 jack pine trees and one aspen tree, were taken from trees that were still standing in the surrounding area. Figure 3.19 is an example of one of the samples taken from a jack pine species near the Wendt site.

During the analysis, one of the samples was too badly burned from the 2005 fire to show any results. So, the analysis focused on the 11 samples that showed only minor burns. The rings from each of the samples were analyzed and counted from the center ring out to the edge. The results showed that most of the trees were between 68 and 84 years old (average age was 75 years old) with two samples much younger at 33 and 38 years old. The rings also suggest that the trees had more nutrients and water in their early years and less of those necessities in later years (see Figure 4.11). A tree under more stress because of these limitations in the soil would grow at a slower rate, which meant that the stem would also be smaller. The smaller the stem the less prone the tree is to tree-throw events.

A tree-stem "cookie" sample was taken from each unit at the Wendt site. Since the trees were burned in 2005, we were forced to measure to the edge that was the least damaged to count the number of rings to determine the age of the tree. Figure 4.11 demonstrates where we chose to measure the rings from the center to the outer edge in Tree-Throw Unit 1.

Figure 4.11

Tree-Ring Analysis of the Tree-Stem "Cookie" From Tree-Throw Unit 1

One of the benefits of taking a tree-stem "cookie" sample is that the center point is not always in the exact center of the tree. We were very fortunate to hit the center of the tree with all the stem-core samples. When you are able to locate the center, one can view as many rings as possible extending out from the center of the stem. The results of the tree-ring analysis showed that the tree of Tree-Throw Unit 1 was approximately 75 years old, the tree of Tree-Throw Unit 2 was approximately 68 years old, and the tree of Tree-Throw Unit 3 was approximately 70 years old. These ages are similar to what we see in the stem-core results. Even though the trees continue to grow over many years because of fire suppression, the lack of certain nutrients in the soil point to the tree stems remaining relatively small. This might mean that tree throw does happen, especially since we do see it at the Wendt site, but that many trees withstand the winds and continue to stand or simply break.

These results, when combined, create a much more distinct picture of the process of tree throw on the Wendt archaeological site. The following chapter will look at the final conclusions from these results.

Chapter V

CONCLUSION

The bigger picture illustrates that tree throw, a type of floralturbation, is an influential form of turbation that affects a larger proportion of archaeological sites than some may realize. David A. Norton (1988) estimates that in a forest, uprooting trees could disturb 90 percent of the soil after 10,000 years (Bonnichsen and Will 1999). When walking through the Wendt site and visually identifying a number of tree throws, one might think Norton's estimate may be accurate in the Boundary Waters Canoe Area Wilderness (BWCAW). According to Mueller and Cline (1959), and Olson and Hole (1967), most of the A and B soil horizons of North America in the northern hardwood regions will be floralturbated over 500 years.

This thesis aimed to dissect the tree-throw area at the Wendt site by looking at what we knew was disturbed (root system, colluvium and depression areas) and what we thought might be undisturbed (Strata 1 – 4). If we were seeing a previous tree-throw occurrence in the undisturbed area, then we should see the same pattern in the disturbed area. These results appear to demonstrate that the disturbed tree throw section does not show all of the same characteristics as the undisturbed section in each unit.

We see in the soil texture of all Tree-Throw Units that the majority of strata in the potentially undisturbed area as well as the root systems are loams. In addition, the colluvium area in all three units are more coarse as sandy loams or very close to sandy loams, which may be because the fine particles of soil are moved by wind and leave the larger particles of sand and gravel to be deposited in the depression. The sand fractionation results do not appear to contribute to identifying tree throw in the potentially undisturbed area for this research. A higher percentage of lithic assemblages appear in the Colluvium with smaller spacing among artifacts (higher number of artifacts per unit volume) than in the potentially undisturbed strata levels. The lithic artifacts are pulled out of the ground with the soil and root system, cling to the roots for a time and eventually fall back into the colluvium to become grouped together. The fact that we see a more sandy soil combined with larger groupings of lithic artifacts in the colluvium area, might signify that the undisturbed area has not been affected by tree throw, and it is possible that the stratigraphy is intact. However, Stratum 2 in both Tree-Throw Unit 1 and Tree-Throw Unit 2 has a larger percentage of lithic artifacts than the other strata in those units, which may point to a cultural level or a pervious tree throw. Of course, we do not see the sandy soil in any levels in the potentially undisturbed strata as we do in the colluvium of the current tree throws. Archaeologists who encounter pockets of coarse sand (as seen in the Colluvium at the Wendt site), particularity if they find concentrations of artifacts in this area, suggests that tree throw may be a variable at their site. Transects across the site where tree throw is suspected could reveal this form of turbation. Using the hydrometer method would be necessary for a more thorough analysis to detect the differences in soil texture.

When statistically analyzing the maximum length of the lithic artifacts, the Colluvium is not different from all strata, but most show differences. Of the 19 pairwise comparisons between the disturbed and potentially undisturbed areas in artifact maximum length, 14 of 19 possible pairwise comparisons are significantly different. However, artifact volume differed in only four out of 19 and in weight only seven out of 19 of the possible pairwise comparisons were significantly different. Whether the difference in artifact characteristics between potentially undisturbed areas and disturbed areas is enough to provide convincing evidence that the undisturbed and disturbed areas are different depends on the artifact characteristic chosen. Attributes for length indicate significant differences between colluvium and strata for all units. Whereas, the attributes for volume show no significant differences in Tree-Throw Unit 1 and Tree-Throw Unit 2 and minimal differences in Tree-Throw Unit 3. Weight shows minimal differences in all three units between the colluvium and the strata.

The trees at the Wendt site seem to be growing predominantly in a loamy soil because the soil texture in Strata 1 though 3 of Tree-Throw Units 1 and 3 and Strata 1 and 2 of Tree-Throw Unit 2 are loams. Loamy soil is normally a good growing soil for trees; however, we see that the soil at the Wendt site is actually nutrient poor, which might mean that tree growth is slow, resulting in trees with smaller stems (height and circumference) and less complex root systems below ground. These results suggest that tree throw may not be extremely prevalent at the Wendt site because trees with smaller stems do not tend to be affected as much by tree throw as taller stems. However, the soil is relatively shallow at this site and if the cultural material is mainly at the Stratum 2 level and the root systems of the trees are in the Strata 1 and 2 levels, we may still see tree-throw disturbance on this archaeological site if the trees get large enough before being killed or blown down. In the last century, fire suppression in the BWCAW has permitted the trees to get larger than during presettlement times when fires occurred more frequently. In summary, it may be reasonable to conclude that the potentially undisturbed regions of the Wendt site could be minimally disturbed.

The results of the NAA and Forest Soil analysis identified Stratum 4 in Tree-Throw Unit 2 as different from Strata 2 and 3 in all units, which may point to a different origin for Stratum 4. However, additional research is needed to characterize possible source-areas for material in Stratum 4 to determine if this is significant.

If the observations of Norton (1988), Mueller and Cline (1959), and Olson and Hole (1967) are correct, tree throw would have a significant effect on archaeological sites within current or formerly forested areas. Even though no single factor was identified to discern that tree-throw did affect the potentially undisturbed section, we do see possible markers in the soil texture and lithic assemblage displacement at the Wendt site. These markers, identified at other sites discussed in the literature review, may assist in preventing misinterpretation of site formation processes, which in turn, might lead to incorrect dating of cultural levels and diagnostic artifacts. The research presented in this thesis provides a starting point for assessing the potential role of tree throw at forested archaeological sites; by comparing measurements of soil properties and the displacement of lithic assemblages within regions such as the BWCAW, we may be able to identify and more accurately interpret the archaeological record.

REFERENCES

REFERENCES

Andrefsky, William Jr.
2005 *Lithics Macroscopic Approaches to Analysis*. 2nd ed. Cambridge University Press, Cambridge, UK.

Bakken, Kent
1997 Lithic Raw Material Resources in Minnesota. *The Minnesota Archaeologist* 56: 51-83.

Batchelor, G.K.
1967 *An Introduction to Fluid Dynamics*. Cambridge University Press, Cambridge, UK.

Benzie, John W.
1977 *Manager's Handbook for Jack Pine in the North Central States*. Forest Service General Technical Rep NC-32. US Department of Agriculture, St. Paul, Minnesota.

Bohn, Carolyn C., and Karl Gebhardt
1989 Comparison of Hydrometer Settling Times in Soil Particle Size Analysis. *Journal of Range Management* 42(1): 81-83.

Bonnichsen, Robson, and Richard F. Will
1999 Radiocarbon Chronology of Northeastern Paleoamerican Sites: Discriminating Natural and Human Burn Features. In *Ice Age People of North America*, edited by Robson Bonnichsen and Karen L. Turnmire, pp. 395-415. Oregon State University Press, Corvallis, Oregon.

Bouyoucos, George J.
1927 The hydrometer as a new method for the mechanical analysis of soils. *Soil Science* 23:343-352.

Brewer, R. and P.G. Merritt
1978 Wind throw and tree replacement in a climax beech-maple forest. *Oikos* 30: 149-152.

Briggs, John M., Katherine A. Spielmann, Hoski Schaafsma, Keith W. Kintigh, Melissa Kruse, Kari Morehouse, and Karen Schollmeyer
2006 Why Ecology Needs Archaeologists and Archaeology Needs Ecologists. *Frontiers in Ecology and the Environment* 4(4): 180-188.

Clark, A.S.
1988 Stratigraphic Charcoal Analysis on Petroraphic Thin Sections: Application to Fire History of Northwestern Minnesota. *Quaternary Research* 30:81-91.

Clayton, William, and Heather Hoffman
2009 Not Just for Canada Anymore: Recent Discoveries of Knife Lake Siltstone Quarries and Workshop Sites on Knife Lake in the Superior National Forest, Lake County, Minnesota. *The Minnesota Archaeologist* 68: 7-20.

Connor, M.A., K.P. Cannon, and D.C. Carlevato
1989 The Mountains Burnt: Forest Fires and Site Formation Processes. *North American Archaeologist* 10:293-310.

Denny, C.S. and J.C. Goodlett
1956 Microrelief from fallen trees. In Surficial geology and geomorphology of Potter County, Pennsylvania. *U.S. Geological Survey, Professional Paper* No. 288, 59-66.

Eash, Neal S., Cary J. Green, Aga Razvi, and William F. Bennett
2008 *Soil Science Simplified*. 5th ed. Blackwell Publishing, Ames, Iowa.

Fitting, James E., Jerry Devisscher, and Edward J. Wahla
1966 *The Paleo-Indian Occupation of the Holcombe Beach*. Anthropological Papers No. 27. Museum of Anthropology, University of Michigan, Ann Arbor.

Frelich, Lee E. and Peter B. Reich
1995 Spatial Patterns and Succession in a Minnesota Southern-Boreal Forest. *Ecological Monographs* 65(3): 325-346.

Friedman, Steven K., Peter B. Reich and Lee E. Frelich
2001 Multiple Scale Composition and Spatial Distribution Patterns of the North-Eastern Minnesota Presettlement Forest. *Journal of Ecology* 89: 538-554.

Heinselman, Miron L.
1969 Diary of the Canoe Country's Landscape. *Naturalist* (Journal of the Natural History Society of Minnesota) 20: 2-13.

Heinselman, Miron L.
1973 Fire in the Virgin Forests of the Boundary Waters Canoe Area, Minnesota. *Quaternary Research* 3: 329-382.

Heinselman, Miron L.
1996 *The Boundary Waters Wilderness Ecosystem*. University of Minnesota Press, Minneapolis.

Holliday, Vance T.
2000 The Evolution of Paleoindian Geochronology and Typology on the Great Plains. *Geoarchaeology: An International Journal*, 15(3): 227-290.

Holmes, W.H.
1893 Vestiges of Early Man in Minnesota. *American Geologist* 11(4): 219-240.

Johnson, Clay
2004 Archaeological Sites and Fire-Induced Changes. *Ancient and Historic Lifeways in North America's Rocky Mountains: Proceedings of the Rocky Mountain Anthropological Conference, Estes Park, Colorado.* Edited by Robert H. Brunswig and William B. Butler.

Logan, Brad, and Matthew Hill, Jr.
2000 Spatial Analysis of Small Scale Debris from a Late Prehistoric Site in the Lower Missouri Valley, Kansas. *Journal of Field Archaeology* 27(3): 241-256.

Luby, Edward
2000 Stratigraphy. In *Archaeological Method and Theory: An encyclopedia*, edited by Linda Ellis, p. 598. Garland Publishing, New York.

Malde, Harold E.
1964 *The Ecologic Significance of Some Unfamiliar Geologic Processes*. In The Reconstruction of Past Environments, assembled by James J. Hester and James Schoenwetter, pp. 7-13. Publication of the Fort Burgwin Research Center, no. 3. Taos, New Mexico.

Mueller, O. P., and M. G. Cline
1959 Effects of mechanical soil barriers and soil wetness on rooting of trees and soil mixing by blow-down in Central New York. *Soil Science* 88:107-111.

Mulholland, Susan C
2011 Phytolith Analysis of Sediments From Three Sites, Knife Lake, Minnesota. Unpublished Report submitted to the Department of Anthropology, St. Cloud State University, St. Cloud, Minnesota.

Nielsen, G.A.
1963 Incorporation of organic matter into the A horizon of some Wisconsin soils under native vegetation. Unpublished Ph.D. thesis, University of Wisconsin, Madison.

Norton, D.A.
1988 Tree Windthrow and Forest Soil Turnover. *Canadian Journal of Forest Research* 19:386-389.

Olson, G.W., and F.D. Hole
1967 The fragipan in soils of northeastern Wisconsin. *Transactions, Wisconsin Academy of Science, Arts and Letters* 56:174-184.

Prettyman, Donald H.
1978 *Soil Survey of Kawishiwi Area, Minnesota: Parts of Lake and Cook Counties in Superior National Forest*. U.S.D.A. Forest Service and Soil Conservation Service and Minnesota Agricultural Experiment Station, St. Paul.

Rudolph, T. D. and Laidly, P. R.
1990. Pinus banksiana Lamb. jack pine. In: Burns, Russell M.; Honkala, Barbara H., technical coordinators. Silvics of North America. Volume 1. Conifers. Agric. Handb. 654. Washington, DC: U.S. Department of Agriculture, Forest Service: 280-293.

Schaetzl, Randall, Donald L. Johnson, Scott F. Burns, and Thomas W. Small
1989 Tree uprooting: review of terminology, process, and environmental implications. *Canadian Journal of Forest Research* 19: 1-11.

Schiffer, Michael B.
1987 *Formation Processes of the Archaeological Record*. University of New Mexico Press, Albuquerque.

Strauss, Alan E.
1978 Nature's Transformations and Other Pitfalls: Toward a Better Understanding of Post-Occupational Changes in Archaeological Site Morphology in the Northeast. Part I: Vegetation. *Bulletin of the Massachusetts Archaeological Society* 39 (2): 47-64.

Swain, Albert M.
1973 A History of Fire and Vegetation in Northeastern Minnesota as Recorded in Lake Sediments. *Quaternary Research* 3: 383-396.

Theler, James L. and Robert F. Boszhardt
2003 *Twelve Millennia, Archaeology of the Upper Mississippi River Valley*. The University of Iowa Press, Iowa City, Iowa.

Ulanova, Nina G.
2000 The effects of windthrow of forests at different spatial scales: a review. *Forest Ecology and Management* 135: 155-167.

Waters, Michael R.
1992 *Principles of Geoarcharology, a North American Perspective*. The University of Arizona Press, Tucson, Arizona.

Wendorff, Michael
1982 The fire areas of Santa Rosa Island: an Interpretation. *North American Archaeologist* 3(2): 173-180.

Wendt, Dan and Anthony D. Romano
2009 Experimental Application of Hammer and Bar Flintknapping to knife Lake Siltstone From Northern Minnesota. *The Minnesota Archaeologist* 68: 21-38.

Wood, Raymond, and Donald Lee Johnson
1978 A Survey of Disturbance Processes in Archaeological Site Formation. *Advances in Archaeological Method and Theory* 1:315-381.

Additional Relevant References (not cited here)

Batchelor, G.K.
1967 *An Introduction to Fluid Dynamics*. Cambridge University Press, Cambridge, UK.

Gallaway, J.M., Y.E. Martin, and E.A. Johnson
2009 Sediment transport due to tree root throw: integrating tree population dynamics, wildfire and geomorphic response. *Earth Surface Processes and Landforms* 34: 1255-1269.

Gavin, Daniel G.
2003 Forest soil disturbance intervals inferred from soil charcoal radiocarbon dates. *Canadian Journal of Forest Research* 33: 2514-2518

Gee, Glendon W. and Dani Or
2002 Particle-Size Analysis. In *Methods of Soil Analysis: Part 4-Physical Methods*, edited by Jacob H. Dane and G. Clarke Topp, pp. 255-293. Soil Science Society of America, Madison, Wisconsin.

Heinselman, Miron L.
1970 The Natural Role of Fire in Northern Conifer Forests. *In* "The Role of Fire in the Intermountain West." (Symposium sponsored by the Intermountain Fire Research Council, Misoula, Montana, Oct. 27-29, 1970), Publication of the School of Forestry, University of Montana, Misoula.

Johnson, D.L. and D. Watson-Stegner
1987 Evolution Model of Pedogenesis. *Soil Science* 143(5): 349-366.

Rich, Roy, Lee Frelich and Peter Reich
2007 Wind-throw mortality in the southern boreal forest: effects of species, diameter and stand age. *Journal of Ecology* 95: 1261-1273.